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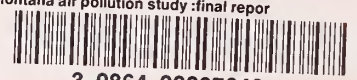


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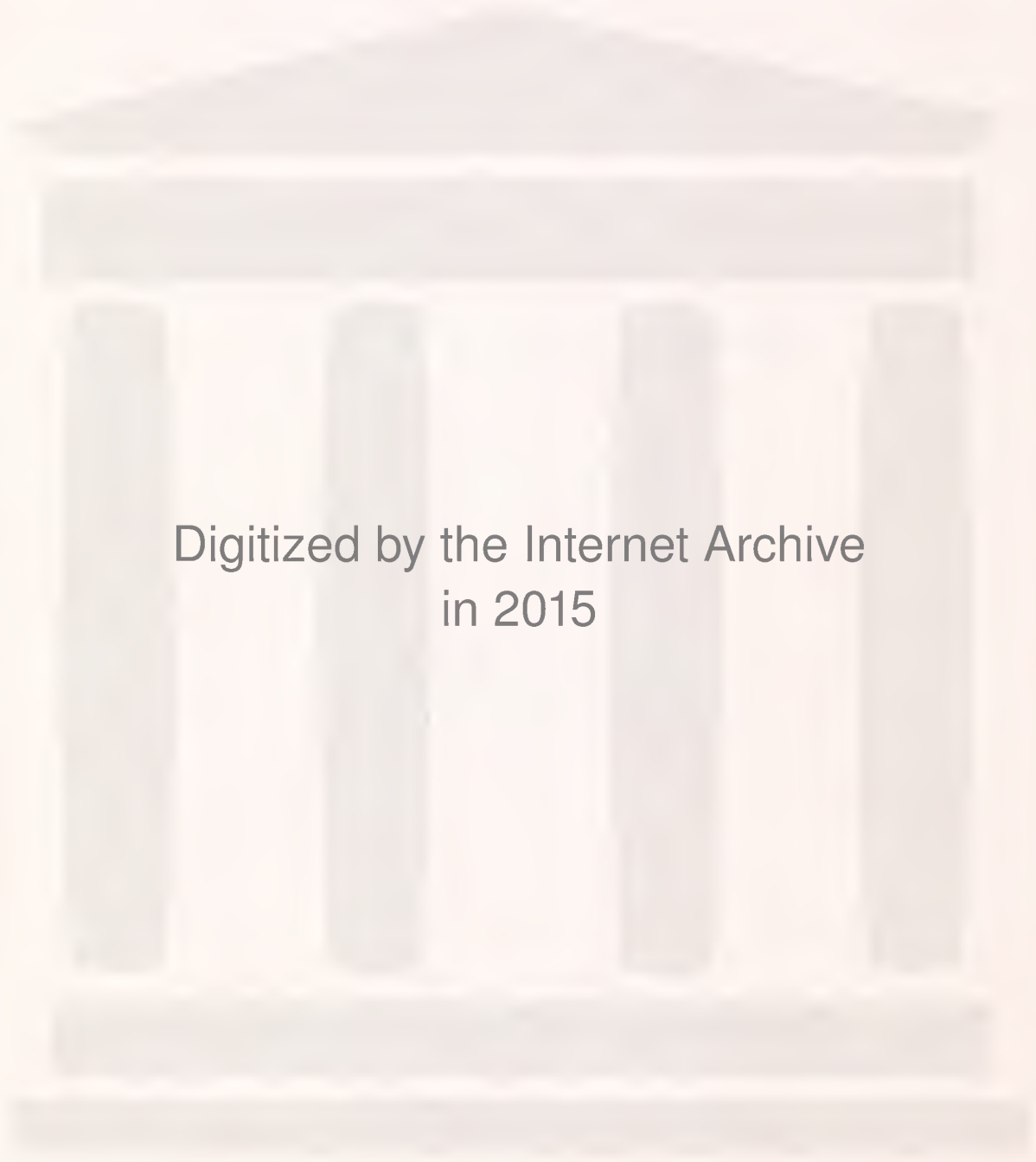
FINAL REPORT

BY

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P R E F A C E

This report summarizes the final results of the Montana Air Pollution Study (MAPS), a major project of the Air Quality Bureau of the Montana Department of Health and Environmental Sciences designed to develop an improved understanding of how air pollution affects human health in Montana. The MAPS project was proposed in response to concern over high death rates from a variety of lung and respiratory ailments in several areas of Montana known to have significant air pollution problems. Missoula County, for example, was found prior to the MAPS project to have a death rate from chronic obstructive pulmonary disease 49 percent above the national average. In Deer Lodge and Silver Bow Counties, the lung cancer death rate was nearly twice the national average. Both men and women suffered the elevated death rates, essentially ruling out occupational pollution exposure as a primary cause.

The principal purpose of MAPS was to determine how air pollution affects the health of people in Montana. The 1977 Montana Legislature funded the proposed MAPS project with \$1.07 million for two years and specified that health effects studies be performed in Anaconda, Billings, Butte, Missoula, Columbia Falls, Colstrip, East Helena, and Hardin. Bozeman and Great Falls were added during the initial study design to provide data from relatively unpolluted areas for comparison with data from the other areas. The 1979 Montana Legislature added \$350,000 and extended the study through June 1981.

The following types of health effects studies were conducted under the project: pulmonary function testing of normal school children and persons with respiratory diseases, screening for the presence of carcinogenic substances in

children's urine in the Butte-Anaconda area, a hospital admissions data study as related to air pollution episodes, and a mortality study to determine numbers of deaths possibly related to air pollution in three counties during the period 1970-1975. Corresponding air monitoring and meteorological data also were gathered, and an update of the state Air Quality Bureau's emission inventory was developed.

The various MAPS activities and results are presented in the series of technical reports listed below. This volume is intended as a general summary of MAPS results for the period July 1977 through June 1980.

List of MAPS Technical Reports

Health Effects

1. Johnson, K.; Schwaller, R.; Wing, B. et al. Pulmonary Function Testing of Patients with Chronic Obstructive Pulmonary Disease (September 1979).
2. Johnson, K.; Gideon, R.; Loftsgaarden, D.; Wing, B. et al. Pulmonary Function Testing of Elementary School Children (October 1979).
3. Johnson, K.; Gideon, R.; Loftsgaarden, D.; Medvec, S.; Simms, M. et al. Relationship Between Human Health and Inhalable Particulates (October 1980).
4. Warren, G.; Rogers, S.; and Medvec, S. Mutagen Screening in an Isolated High Lung Cancer Mortality Area of Montana (June 1979).

Air Quality

1. Gelhaus, J. Air Quality Data Summaries for Anaconda-Butte, Billings, Missoula, and Columbia Falls/Hardin/East Helena/Colstrip (February 1981).
2. Robbins, H.; Driscoll, P.; Myren, B. et al. Air Monitoring Instrumentation (October 1979).

Meteorology/Modeling

1. Gelhaus, J. et al. Meteorological Summary - First Year (July 1979).
2. Gelhaus, J. and Harner, S. Deer Lodge Valley Dispersion Study (July 1979).
3. Gelhaus, J. Meteorological Summary - Billings (February 1981).
4. Gelhaus, J.; Machler, M.; and Stewart, T. Montana Air Resources Modeling System (August 1979).
5. Middlemist, T.; Robbins, H; and Zimmerman, L. Missoula Valley Dispersion Study (September 1980).
6. Nelson, B.; Machler, M; and Robbins, H. Deer Lodge Valley Dispersion Study (October, 1980)

Emission Inventory

1. Bohn, R.; Cowherd, C.; Keller, R; and Raisch, R. Update and Improvement of the Emission Inventory for MAPS Study Areas (November 1979).
2. Raisch, R.; Williams, G.; Bohn, R.; and Cowherd, C. A Study of the Feasibility of Performing an Inventory of Historical Emissions at Butte and Anaconda, Montana (November 1979).

Systems Design

1. Lynn, D. et al. Computer Information System Development (November 1979).

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SUMMARY OF CONCLUSIONS

Introduction

The Montana Air Pollution Study (MAPS) is a major four-year study by the Air Quality Bureau of the Montana Department of Health and Environmental Sciences of the effects of air pollution on human health in several of Montana's urban areas. Funded initially by the 1977 Montana Legislature for two years and then extended by the 1979 session for an additional two years, MAPS was completed in June 1981 at a cost of \$1.5 million.

The 1977 Montana Legislature requested that air pollution-health effects studies be implemented in the cities of Anaconda, Billings, Butte, and Missoula, as well as in the towns of Columbia Falls, Colstrip, East Helena, and Hardin. Bozeman and Great Falls were added during the initial study design to provide data from relatively unpolluted areas for comparative purposes. The study areas are located for the most part in mountain valleys or river canyons, where prolonged periods of air stagnation are common during the late fall and winter. Potential air pollution sources in the study areas include, among others, automobiles, paved and unpaved roads, agricultural tillage, wood home heating, smelters, oil refineries, open-pit mines, pulp paper plants, and industrial tailings. The following health effects studies were performed during the project: lung (pulmonary) function testing of school children and persons with respiratory diseases, screening for the presence of possible carcinogenic substances in the air and in children's urine in the Butte-Anaconda area, and a mortality study to determine numbers of deaths possibly related to air pollution in three counties during the period 1970-75.

Results

Pulmonary Function Testing

Results of comparative pulmonary function tests conducted in Anaconda, Billings, Butte, Great Falls, and Missoula during the 1978-79 school year showed that Great Falls children, who were exposed to the least urban air pollution levels, had the best pulmonary performance. In contrast, children from Missoula, with the highest particulate levels, and Anaconda, with the highest sulfur dioxide levels, had the worst pulmonary performance. Billings and Butte children were found to have readings between the two extremes. A separate analysis of various socio-economic factors in the study cities revealed that those factors were not responsible for differences in pulmonary ability demonstrated among the five cities. The study also revealed that in most cases females reacted more adversely to air pollution than males.

An analysis of pulmonary function measurements among Missoula children during the 1978-79 and 1979-80 school years showed consistently that as particulate levels in the air increased, pulmonary performance decreased. No significant decrease in the children's pulmonary ability was demonstrated following exposure to extremely high levels of volcanic ash in a separate analysis of data collected one week after the eruption of Mount Saint Helens on 18 May 1980.

In 1978-79, an eighteen-month study of 84 Missoula adults with chronic obstructive pulmonary disease (COPD) was conducted. Results also showed decreasing pulmonary performance, as well as notable increases in coughing, wheezing, and shortness of breath, with increasing air pollution levels.

Carcinogenic Screening in Butte-Anaconda

Measurement of the mutagenic potential of substances has become a standard procedure throughout the world to assess the carcinogenicity of substances; i.e., their potential for causing cancer. The Ames test predicts whether a substance will be carcinogenic on the basis of its mutagenicity to certain strains of bacteria. The MAPS project adopted this specific methodology to assess cancer risk in the Butte-Anaconda area.

In 1978-79, urine testing was conducted at three elementary schools in Anaconda and Butte, where lung cancer rates are high, and at one school in Bozeman, where lung cancer rates are low. Eleven Butte children out of 80 sampled had mutagen levels considered to be significantly elevated. This is the first time elevated mutagen levels have been demonstrated in the urine of non-smokers. No Anaconda children reached these levels, and the levels of mutagen among Bozeman children were not significant. The Butte children with elevated mutagen levels lived relatively near Front Street, a major east-west thoroughfare running parallel to the railroad tracks. It is suspected that these students are exposed to high levels of polyaromatic hydrocarbons, among them benzo(a)pyrene, known carcinogens that are derivatives of diesel exhaust and other products of combustion. The different mutagen levels between Anaconda and Butte test groups support the existing assumption that the two communities differ in distribution of carcinoma types and risk patterns between men and women.

Mortality Study in Three Counties

A 1974 review of Montana's vital statistics revealed that some counties had abnormally high death rates from asthma, chronic bronchitis, emphysema, cerebrovascular disease, and lung cancer, especially within the 40-65 age group. After

an analysis of the data had been completed, Deer Lodge, Lake, and Silver Bow Counties were selected for a more detailed investigation of possible causes for the high death rates. Although strong suspicion remains that exposure to ambient air pollution may have contributed to high death rates among residents of the three counties from lung cancer, respiratory diseases, and cerebrovascular disease, it cannot be proven conclusively because of the variable of undocumented smoking habits. There may be a synergistic effect from air pollution exposure and smoking.

Conclusion

Prior to undertaking this study, pollution researchers, such as Drs. Benjamin Ferris of Harvard University and Ian Higgins of the University of Michigan, were of the opinion that a correlation between increased air pollution and decreased lung performance could not be demonstrated at air pollution levels found in Montana. MAPS, however, has confirmed the hypothesis that increased air pollution levels cause a decrease in lung functioning.

CHAPTER I

INTRODUCTION

The concept of developing a state study of air pollution health effects arose after a review of death certificates by the Department's Bureau of Records and Statistics had shown unusually high death rates from chronic obstructive pulmonary disease (COPD) and lung cancer in several Montana counties. Since many researchers and interested observers felt that high air pollution levels caused or aggravated these categories of lung diseases, a more extensive study of the subject seemed warranted. Consequently, the Department recommended to the Montana Legislature that a study be undertaken, and the 1977 Legislature enacted House Bill (HB) 250 to mandate and to fund such a project.

In response to the passage of HB 250, the Air Quality Bureau developed a proposed project plan in May 1977 for the Montana Air Pollution Study (MAPS), to be conducted during the 1977-79 biennium. The proposed plan specified three major goals to be pursued under the MAPS project:

- ° Develop for each study area a comprehensive body of information on air pollution levels, meteorology, pollutant emissions, and topography, and determine how these factors relate to the effects or impacts on the public;
- ° Determine where possible the health impacts of selected air pollutants on the populace of specific areas of the state (areas designated in the law are Butte-Anaconda, Billings, Missoula, Columbia Falls, East Helena, and the Colstrip-Hardin southeast coal development region); and

- ° Develop an early warning system to prevent the occurrence of high air pollutant levels that could cause possible health damage.

In addition to these policy-level goals, the proposed plan further defined seven specific operational objectives designed to implement the following goals:

1. Comprehensive information system;
2. Air resources modeling system;
3. Air resources data bank;
4. Ambient air monitoring;
5. Meteorological studies;
6. Emission inventory; and
7. Health effects monitoring.

The May 1977 project plan also defined an organizational structure to coordinate the MAPS project within the Air Quality Bureau and established five statewide advisory committees (Appendix A) to assist the Bureau in providing all relevant expertise available in the state. It was decided early in the project's planning stages to undertake the study "in-house" rather than to contract the entire project to a commercial consulting firm that conducts contract research in the environmental sciences. This decision was made not only to reduce costs, but also to integrate the MAPS project more closely into the Bureau's regular functions.

During the initial period of contact with various consulting firms, however, GCA Corporation of Massachusetts proposed to undertake as a short task the next steps in project development. The proposal was accepted as a means of continuing project development without committing the project to a consulting firm. GCA then undertook to define detailed tasks and to make cost estimates based on the proposed project plan. GCA personnel worked closely with the Bureau's

staff, the MAPS project coordinator, and the advisory committees in order to define the tasks needed to meet the overall goals and objectives of the MAPS project. In November 1977, GCA issued its final report entitled "Initial Task Planning." The Bureau then prioritized the various tasks into three groups, as listed in Table 1. The first group of tasks was considered to be essential to the project, requiring immediate implementation. The second group also was important but could be implemented at a later period in the project. The third group of tasks was to be included in the project only if budgetary constraints permitted.

TABLE 1

PRIORITY GROUPING OF TASKS

- PRIORITY I. These tasks were essential to the basic core of MAPS, requiring immediate implementation.
- Pulmonary function studies and associated support efforts
 - Carcinogen/mutagen screening study
 - Morbidity data studies
 - Mortality studies
 - Areawide total and respirable particulate monitoring, with associated analyses
 - Continuous gaseous pollutant monitoring
 - Meteorological support monitoring in Missoula and Billings
 - Basic design of data management system, as well as standards and effects subsystem
- PRIORITY II. These tasks were required for the completion of the overall MAPS project objectives, although less fundamental or of less urgency than Priority I.
- Initial development in support of episode prevention system
 - Emission inventory update and improvement
 - Meteorological support monitoring in Butte and Anaconda
 - Basic design and development of emission inventory and meteorological modeling systems
 - Additional monitoring equipment for sulfur dioxide and special studies
- PRIORITY III. These tasks were considered desirable and supportive of MAPS project objectives but had to be held in abeyance pending the outcome of procurements.
- Additional data studies of mortality in Billings and Missoula, and of physician visits in Billings
 - Alternative carcinogen/mutagen screening programs
 - Additional monitoring equipment for special indoor/outdoor studies
 - Special sulfate characterization study
 - Additional meteorological support monitoring
 - Further emission inventory development
 - Special emission factor development work
 - Further historical emission inventory
 - Extended data systems and modeling capability

Overview of MAPS Activities

This section includes brief descriptions of the MAPS activities; i.e., monitoring of air quality and meteorology, emission inventory efforts, and health effects research. A comprehensive information system was designed to tie these various activities together in order to improve understanding of how air pollution affects human health in Montana.

Air Quality Monitoring

One of the major functions of the MAPS project was to provide a comprehensive data base on ambient air pollutant levels, which required considerable expansion of the Bureau's ambient air monitoring network in the study cities. As a result, each study city had at least one major monitoring site to monitor concentrations of sulfur dioxide, nitrogen dioxide, ozone, total suspended particulates, and respirable particulates. The monitoring of respirable particulates was especially critical in assessing the health effects of air pollution in the state.

Meteorological Monitoring

In order to assess the effect of Montana's complex mountain-valley terrain on air pollution dispersion, the MAPS project established an extensive network to monitor meteorology in the study areas. Surface wind stations were located at the major air quality monitoring sites and at several other urban sites as dictated by the area's topography. In addition, solar radiation, atmospheric turbidity, relative humidity, and barometric pressure were included. In the major study cities of Anaconda, Billings, and Missoula, significant studies of upper air movements and inversions also were implemented. These efforts were designed to provide forecasting capabilities through the use of air pollution modeling with regard to topographical conditions found in Montana.

Emission Inventory Efforts

The MAPS project included two activities in the emission inventory area; i.e., a major improvement and expansion of the Bureau's emission inventory of air pollution sources in Montana, and a feasibility study as to the possibility of conducting a historical emission inventory in the Butte-Anaconda area. The expansion of the Bureau's inventory was undertaken by means of a contract with Midwest Research Institute of Kansas City, Missouri. The inventory was designed to provide monthly rather than annual estimates of pollutants emitted in Deer Lodge, Missoula, Silver Bow, and Yellowstone Counties. The change from an annual to a monthly inventory was implemented to account for strong seasonal patterns in ambient air quality levels and meteorology. An extensive attempt was made not only to estimate emissions from major industrial sites in the four counties, but also to evaluate the emissions from such area sources as paved and unpaved roads, agriculture, slag dumps, mine haul roads, and refinery coke stockpiles.

The historical emission inventory arose from consideration of the long incubation periods involved in the development of lung cancer and chronic lung diseases. Since these diseases develop over a lifetime, it seemed appropriate to attempt to assess past emission levels. Therefore, a contract was let to Historical Research Associates of Missoula, Montana, to ascertain the feasibility of compiling a quantitative inventory from historical information. The feasibility study was conducted in the Butte-Anaconda area, where high death rates from lung cancer and chronic lung diseases have been noted.

Health Effects Studies

A large amount of medical and scientific literature exists concerning a wide variety of air pollution health effects that have occurred in the United States and throughout the world. These health effects include both acute effects, which occur in response to daily changes in air pollution levels in any given location, and chronic effects, which occur over longer periods of from several years to a lifetime.

A number of effects already had been observed to some extent in Montana. As mentioned earlier, several counties of the state have high death rates for groups of diseases generally believed to be attributable to air pollution exposures. Research studies by University of Montana students in Missoula have suggested a possible association between particulate levels and respiratory-related hospital admissions. Toxic fluoride effects have occurred in animals, elevated blood lead levels have been observed in children, and many physicians have related incidents of increased respiratory symptoms apparently due to air pollution exposures. Like the general body of medical and scientific literature, this miscellaneous collection of knowledge was enough to cause concern from medical and public health officials, as well as from individual citizens, but it was not the type of specific, quantitative information required to support major public policy judgments. Consequently, the MAPS research project was designed to provide more quantitative information, developed specifically with respect to the air pollution levels, the meteorology, and the population of Montana.

As part of its design for development of the MAPS project, the Bureau formed the Health Effects Advisory Committee comprised of Montana physicians and other persons interested in and knowledgeable about the health effects of air pollution (Appendix A-1). This committee, headed by Dr. Kit G. Johnson, met with

national experts in air pollution and health, including Dr. Benjamin Ferris, Harvard School of Public Health; Dr. Carl Hayes of the Environmental Protection Agency's health effects research group; and Dr. Douglas Hammer, an independent air pollution research consultant from North Carolina. This was coupled with a review of literature on recent air pollution and health research, as well as through numerous meetings and long distance phone and small committee conferences. The Committee then developed an approach to the health effects studies for the MAPS project using the most proven study techniques available. The major components included the following:

- 1) A comparison of children's pulmonary function among communities with different types and levels of air pollution;
- 2) A longitudinal study of the acute association of changing air pollution levels on the pulmonary function of Missoula children;
- 3) A longitudinal study of the acute association of changing air pollution levels on the pulmonary function and respiratory symptoms of a group of Missoula adults;
- 4) A statewide study of hospital admissions for respiratory illness;
- 5) A mutagenicity study comparing the Butte-Anaconda area with cleaner areas of the state;
- 6) A mortality study with retrospective analysis of causes of death as shown in death certificates from counties with high rates of air pollution-associated diseases.

The results of each health effects component will be discussed thoroughly in this final report.

The results contained in this report summarize the findings of the interim reports listed in the Preface. The period covered is July 1977 through June 1980; final data analysis and report writing were conducted during the period July 1980 to June 1981. Recent findings on the relationship between human health and air pollution in Montana, not discussed in the previous MAPS reports, are included in this final MAPS document.

CHAPTER II

AIR QUALITY/METEOROLOGY MONITORING

This section describes the findings of five reports published previously by the Montana Air Pollution Study with regard to air pollution levels and meteorological conditions. One of these reports defines air pollution levels in the MAPS study areas specified by the 1979 Montana Legislature, while four reports deal with results of extensive meteorological studies conducted in three principal Montana valleys to assess the influence of topography on air pollution dispersion.

Air Quality Data Summaries

Final MAPS air quality data are presented in a report entitled "Air Quality Data Summaries for Anaconda-Butte, Billings, Missoula, and Columbia Falls/Hardin/East Helena/Colstrip" (February 1981), written under contract by Bison Engineering/Research, Helena, Montana. Air pollution levels recorded in the MAPS study areas and listed in the Bison report are summarized here. It should be noted that comparisons are made throughout the summary to federal and Montana ambient air quality standards. The fact that values observed at some stations exceeded these standards does not necessarily constitute a violation. Other factors such as siting criteria and monitoring methodology must be considered before a violation exists.

Anaconda-Butte

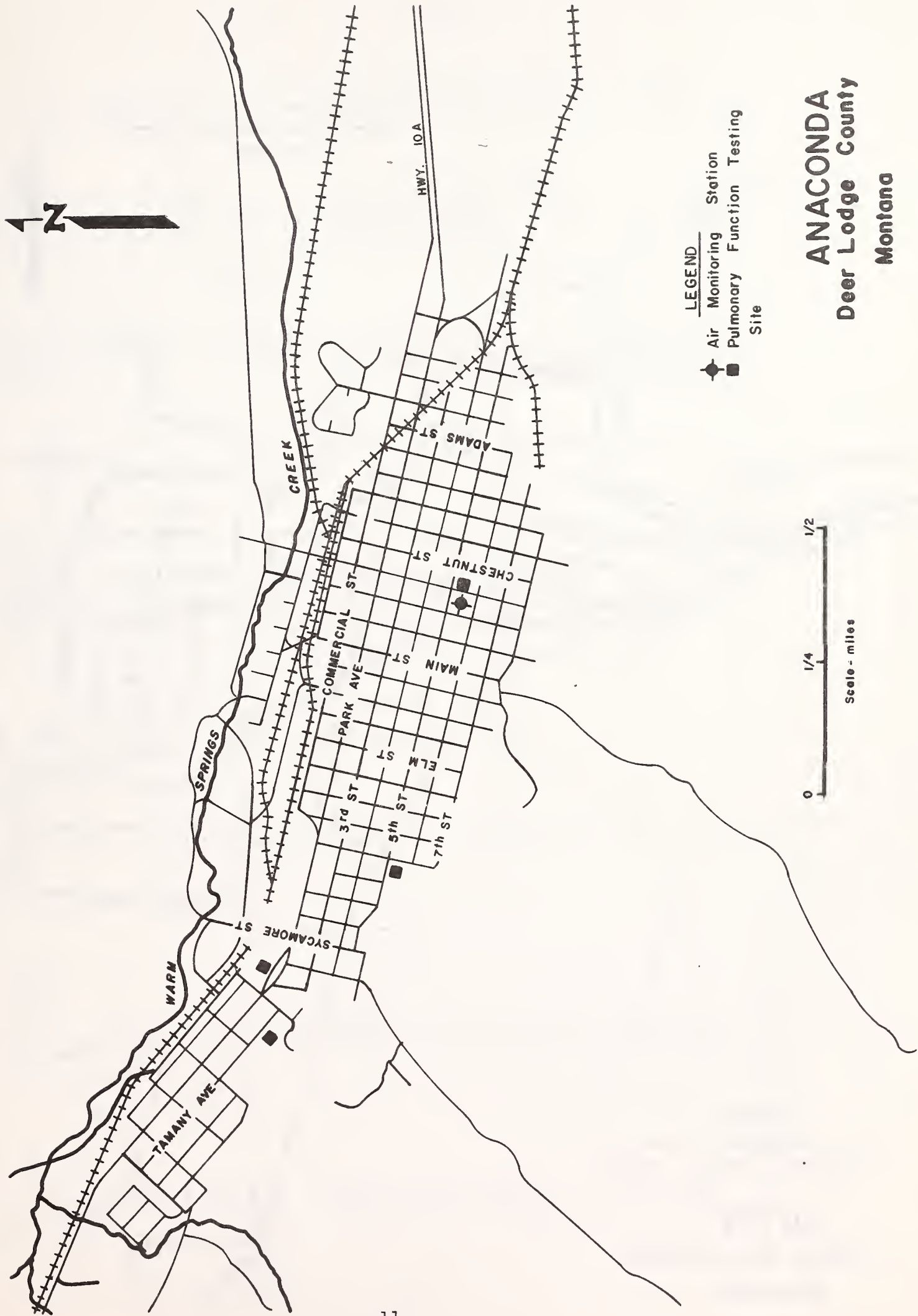
The Anaconda area's elevation varies from about 5200 feet above sea level in the urban area to 10,600 feet in the mountains to the south. Anaconda is located at the southern end of the Deer Lodge Valley and northeast of the Anaconda-Pintlar Wilderness area. The valley experiences temperature

inversions, which tend to trap and to hold pollutants, approximately 40 percent of the time on an annual average. The Anaconda Company's copper smelter, on the eastern edge of Anaconda, was the major industrial complex in the area and the source of approximately 80 percent of Montana's sulfur dioxide emissions. The smelter was also a source of particulates. (The smelter was closed in the autumn of 1980, and reopening is not anticipated at this writing.) Air pollution monitors are shown in Figure 1.

The populated areas of Butte and vicinity range in elevation from approximately 5200 feet above sea level near the Stauffer Chemical Plant (about six miles west of Butte) to approximately 6000 feet above sea level at Walkerville (about one mile north of Butte). The city of Butte is located about four miles west of the Continental Divide. The area experiences a climate characteristic of its high elevation; i.e., extreme cold spells, long snow cover, and a short growing season are normal for the area. Frequent temperature inversions, especially in the winter months, tend to trap and to hold pollutants. Major potential sources of air pollution in the area include a large open-pit copper mine, an ore concentrator, an elemental phosphorous plant, a tepee burner, and several asphalt plants. Automobiles, home heating devices, and windblown or fugitive dust also contribute to air pollution levels in the Butte area. Air pollution monitors are shown in Figure 2.

Tables 2 and 3 list air quality levels measured at the principal MAPS air monitoring stations situated at Lincoln School and Hebgen Park, located in residential areas of Anaconda and Butte, respectively. Tables 4 and 5 list respective Montana and federal ambient air quality standards. Data were collected on concentrations of total suspended particulates, inhalable particulates (suspended particulates less than 15 microns in diameter that are usually capable of entering the human respiratory system and causing respiratory

Figure 1



ANACONDA
Deer Lodge County
Montana

Figure 2

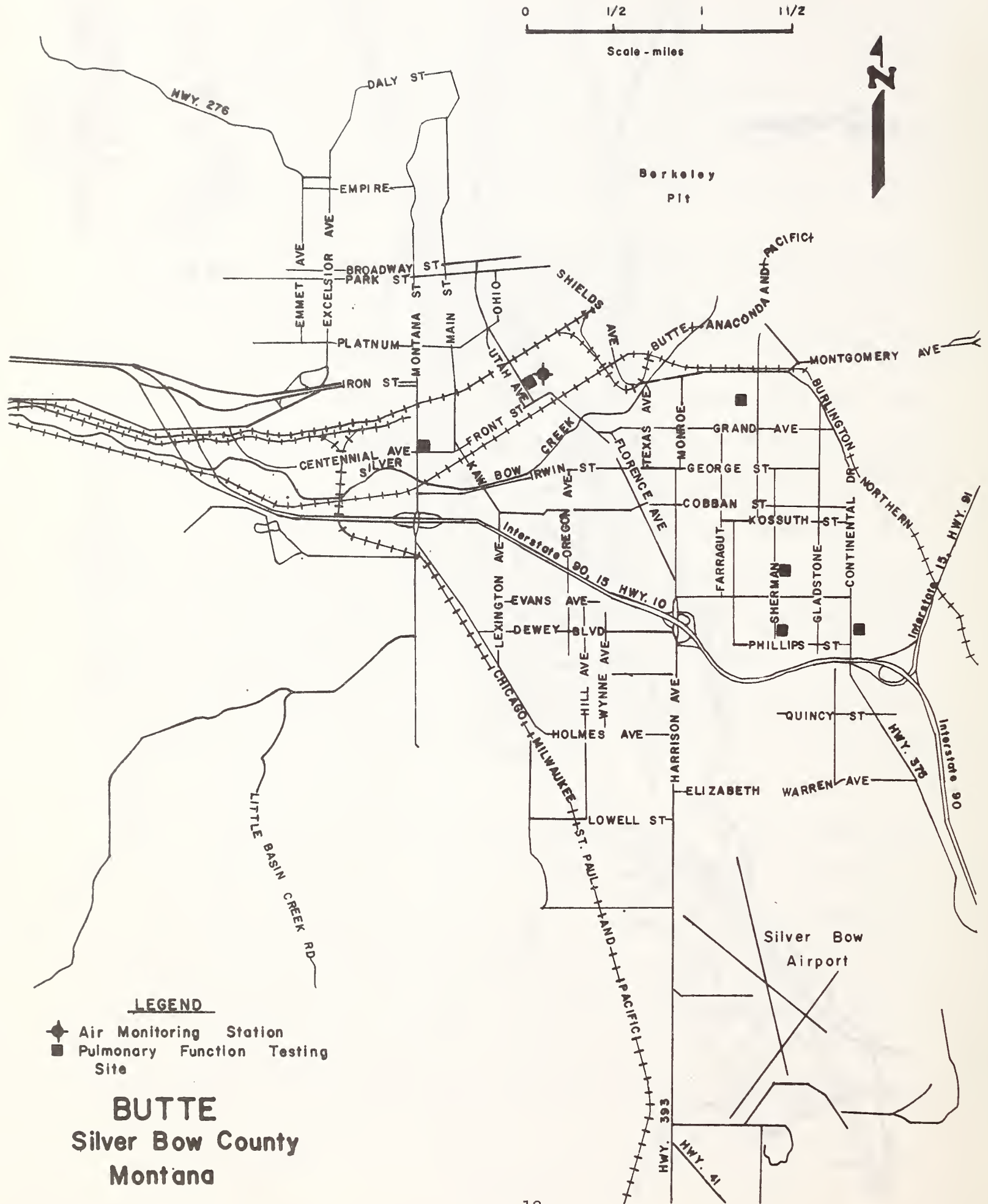


TABLE 2

ANACONDA (LINCOLN SCHOOL) MONTHLY AVERAGE AIR QUALITY SUMMARY

Month	Total Susp. Particulates+	Suspended Part. 2.5 microns	Suspended Part. 2.5 to 15 microns	Sulfur* Dioxide	Nitrogen* Dioxide	Ozone*
Mar 78	---	---	---	0.01	---	---
Apr	---	---	---	0.04	---	---
May	25	---	---	0.00	---	---
Jun	45	---	---	0.00	---	---
Jul	41	---	---	0.03	0.004	---
Aug	41	12	13	---	0.003	---
Sep	39	13	13	---	---	---
Oct	55	11	29	0.03	0.004	---
Nov	46	20	17	0.03	0.011	---
Dec	22	17	8	0.02	---	0.028
Jan 79	39	30	10	0.03	0.017	0.023
Feb	23	19	6	0.05	0.009	0.034
Mar	90	12	36	0.03	0.005	0.036
Apr	40	36	13	0.00	0.004	0.037
May	55	8	30	0.02	0.004	0.038
Jun	47	7	28	0.01	0.003	0.035
Jul	54	11	28	0.01	0.003	0.038
Aug	51	13	19	0.03	0.003	0.032
Sep	90	14	30	0.07	---	0.029
Oct	74	14	22	0.04	---	0.023
Nov	89	26	27	0.04	---	0.026
Dec	53	10	28	0.01	---	0.028
Jan 80	49	23	11	0.04	---	0.023
Feb	76	19	22	0.04	---	0.028
Mar	60	9	30	0.02	---	0.029
Apr	88	11	26	0.05	---	0.015
May	42	9	12	0.08	---	---
Jun	53	7	16	0.05	---	---

*Values in parts per million

+Values in micrograms per cubic meter

TABLE 3

BUTTE (HEBGEN PARK) MONTHLY AVERAGE AIR QUALITY SUMMARY

Month	Total Susp.+ Particulates	Suspended Part. 2.5 microns	Suspended Part. 2.5 to 15 microns	Sulfur* Dioxide	Nitrogen* Dioxide	Ozone	Carbon Monoxide
Mar 78	---	---	---	---	---	---	---
Apr	---	---	---	---	0.006	0.024	---
May	40	---	---	---	0.000	0.037	---
Jun	56	---	---	---	0.010	0.034	---
Jul	53	---	---	0.006	0.013	0.030	0.2
Aug	58	---	---	0.007	---	0.029	0.2
Sep	59	---	---	---	0.014	0.019	---
Oct	92	---	---	---	---	0.017	1.0
Nov	83	24	22	---	---	0.012	1.7
Dec	69	36	14	---	0.035	0.010	---
Jan 79	92	---	---	0.010	0.063	0.005	---
Feb	59	29	20	0.011	0.039	0.017	---
Mar	102	20	36	0.011	---	0.023	---
Apr	58	12	36	0.007	---	0.034	---
May	75	12	37	0.007	---	0.033	---
Jun	84	11	36	---	---	0.031	---
Jul	89	16	45	---	---	0.029	0.8
Aug	72	12	26	---	---	0.029	1.3
Sep	101	17	34	---	0.018	0.016	0.9
Oct	88	23	36	---	0.008	0.013	0.9
Nov	128	32	32	---	0.016	0.007	0.9
Dec	128	26	31	---	0.019	0.010	---
Jan 80	110	38	37	---	0.026	0.008	---
Feb	101	26	26	---	0.029	0.011	---
Mar	80	21	25	---	0.016	0.023	---
Apr	109	21	45	---	0.015	0.030	---
May	66	18	14	---	0.013	0.039	---
Jun	46	13	16	---	0.012	0.013	---

*Values in parts per million

+Values in micrograms per cubic meter

TABLE 4
MONTANA AMBIENT AIR QUALITY STANDARDS

Pollutant	Standard		Averaging Time
	(ug/m ³)	(ppm)	
Carbon Monoxide	---	23	1-hour*
	---	9	8-hour*
Fluoride(forage)	---	20 ug/g --	Month [†]
Hydrogen Sulfide	---	0.05	1-hour*
Lead	1.5	---	90-day [†]
Nitrogen Dioxide	---	0.30	1-hour*
	---	0.05	Annual
Ozone	---	0.10	1-hour*
Settled Particulate	---	10g/m ² ---	30-day [†]
Sulfur Dioxide	---	0.50	1-hour ^a
	---	0.10	24-hour*
	---	0.02	annual
Total Suspended Particulates	200	---	24-hour*
	75	---	Annual
Visibility	--- 3x10 ⁻⁵ per meter		Annual

*Not to be exceeded more than once per year

[†]Not to be exceeded

^aNot to be exceeded more than eighteen times in any twelve consecutive months

TABLE 5
FEDERAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Primary (ug/m ³) (ppm)		Secondary (ug/m ³) (ppm)		Averaging Time
Total Suspended Particulates	75 260	--- ---	60 150	--- ---	Annual 24-hour*
Sulfur Dioxide	80 365 ---	0.03 0.14 ---	--- --- 1,300	--- --- 0.5	Annual 24-hour* 3-hour*
Carbon monoxide	10,000 40,000	9.0 35.0	--- ---	--- ---	8-hour* 1-hour*
Photochemical Oxidants	240	0.12	---	---	1-hour ⁺
Hydrocarbons	160	0.24	---	---	3-hour (6-9 a.m.)*
Nitrogen Oxides	100	0.05	---	---	Annual
Lead	1.50	---	---	---	Quarter

*Not to be exceeded more than once/year.

⁺Not to be exceeded more than one day a year.

insult), trace elements, and gaseous pollutants. Total suspended particulate data from Butte indicated concentrations in excess of the federal primary and secondary as well as of the Montana twenty-four hour standards. The federal primary and secondary as well as Montana annual particulate standards were also exceeded. Butte recorded the higher particulate levels of the two communities. Highest monthly average particulate concentrations generally occurred during the autumn, whereas lowest concentrations occurred during the winter.

Although no federal or Montana standard has been adopted, inhalable particulate data revealed interesting trends and provided valuable data for the health effects studies conducted in Anaconda-Butte. Generally, the inhalable particulates' fine fraction (less than or equal to 2.5 microns, which are capable of entering the deep lung) had highest concentrations in the late autumn or winter, and lowest concentrations in the late spring and summer. The fine fraction generally contributed 33 to 50 percent of the total inhalable particulates. The coarse fraction (between 2.5 and 15 microns, which usually becomes trapped in the body's nasal passages and upper respiratory system) did not show as definite trends as the fine fraction. Generally, the coarse fraction contributed 50 to 67 percent of the total fine particulates.

Trace element data generally revealed differences between the Anaconda and Butte areas. Trace element data revealed higher levels of aluminum, copper, iron, manganese, and nitrate at Hebgen Park in Butte, with higher levels of arsenic, cadmium, nickel, zinc, and sulfates at Lincoln School in Anaconda.

Among gaseous pollutants, ozone data collected in the Anaconda-Butte area revealed levels below the federal and Montana standards for the second-highest readings. Highest readings were recorded in Butte at Hebgen Park, but the overall average ozone concentration was higher at Lincoln School in Anaconda. Highest concentrations occurred during the autumn and winter, whereas lowest concentrations occurred during the late spring and early summer. Carbon

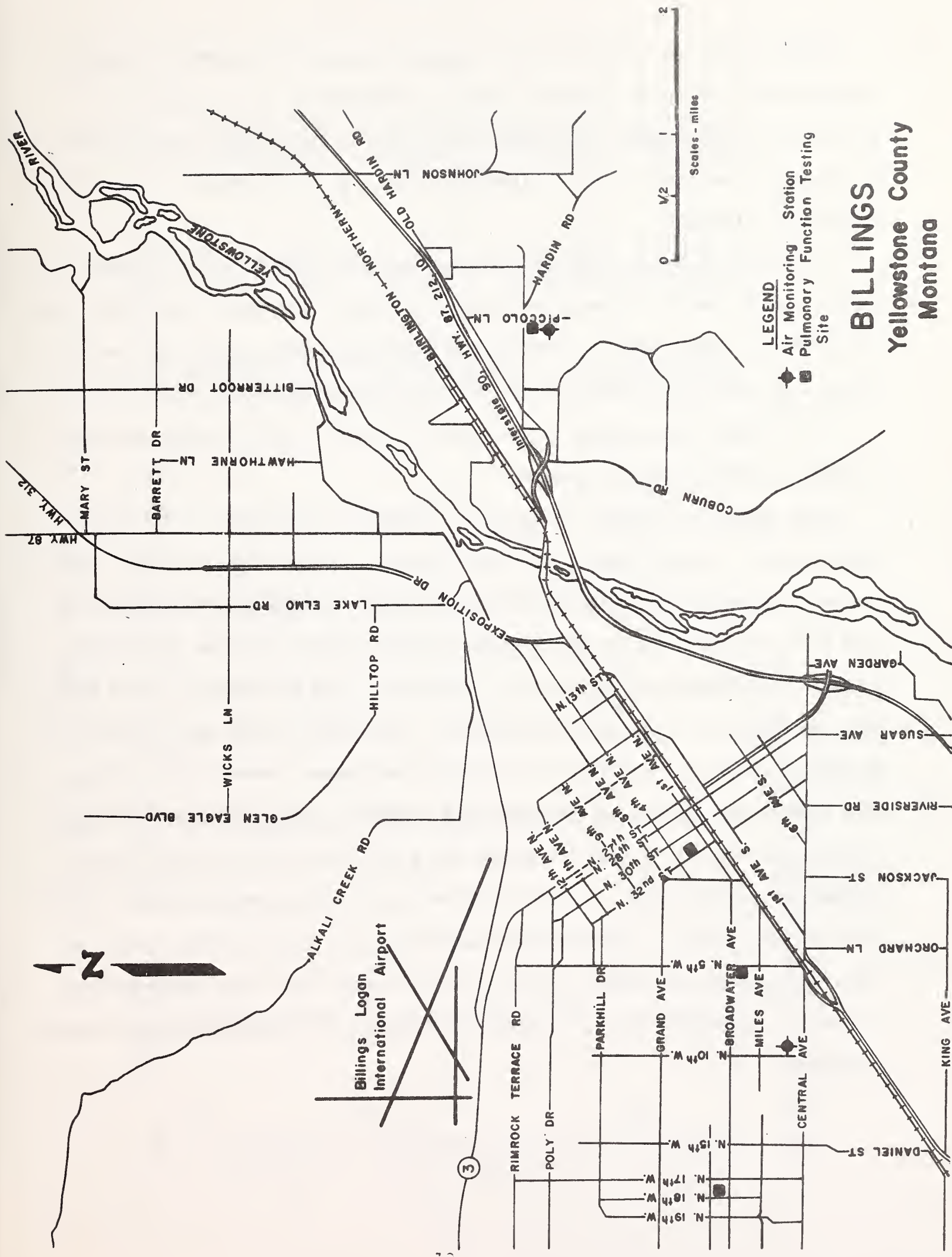
monoxide was measured only in Butte, and concentrations were below the federal and Montana standards. Nitrogen dioxide data in Anaconda and Butte revealed levels below both the federal and Montana standards. Sulfur dioxide concentrations were recorded in both Anaconda and Butte, with much higher levels recorded in Anaconda due to the copper smelter emissions. Levels in excess of the federal and Montana standards were recorded in the Anaconda area.

Billings

The Billings area's elevation varies from about 3100 feet to 3600 feet above sea level. The area is located between the Great Plains and the Rocky Mountains, and therefore has a climate characteristic of both regions. The Yellowstone River Valley, which includes a major portion of the city of Billings, has a major influence on the city's climate, as it influences the local wind patterns that are important in determining where and how quickly air pollutants are dispersed. Air pollution monitors are shown in Figure 3.

Billings and Laurel, located fifteen miles southwest of Billings, contain significant industries. Three refineries, a coal-fired power plant, a sugar beet factory, and a sulfur plant are all important business activities in the area, as well as significant sources of air pollution. These sources, along with automobile and home heating emissions, contribute to air pollution levels observed in the area.

Figure 3



- LEGEND**
- Air Monitoring Station
 - Pulmonary Function Testing Site



BILLINGS
 Yellowstone County
 Montana



Table 6 lists air quality levels measured at the principal MAPS air monitoring station situated at Central Park in a residential area of central Billings. Total suspended particulate data from Billings showed concentrations in excess of the federal primary standard as well as of the federal secondary and Montana standards.

Although no federal or Montana standard has been adopted, inhalable particulate data revealed interesting trends and overall averages. Generally, the fine fraction contributed the most to the total inhalable particulate levels during the winter, with the least contribution occurring in the late summer.

Trace element data generally revealed low levels of all elements analyzed. No ambient standards were exceeded.

Among gaseous pollutants, ozone data collected at two sites in Billings showed levels near the federal one-hour standard, but in slight excess of the Montana standard at both locations. Lowest concentrations occurred during the late fall and early winter, while highest concentrations occurred during the summer. Carbon monoxide data for two locations in the Billings area were below both the federal and the Montana standards. No seasonal trend was apparent. Nitrogen dioxide data collected at two locations showed concentrations below both federal and Montana ambient standards. Highest concentrations of nitrogen dioxide occurred during the late autumn and early winter, with lowest concentrations during the summer. Sulfur dioxide concentrations were measured at four stations during MAPS. Concentrations were below the federal and Montana standards at all stations except the Laurel Farm station, which had concentrations recorded in excess of the one-, three-, and twenty-four hour Montana and federal standards.

TABLE 6

BILLINGS (CENTRAL PARK) MONTHLY AVERAGE AIR QUALITY SUMMARY

Month	Total Susp. Particulates ⁺	Suspended Part. <2.5 microns ⁺	Suspended Part. 2.5 to 15 microns ⁺	Sulfur Dioxide*	Nitrogen Dioxide*	Ozone
Jun 78	79	---	---	0.002	0.011	---
Jul	82	---	---	0.006	---	0.027
Aug	109	---	---	0.008	0.017	0.016
Sep	82	25	13	0.011	---	0.014
Oct	85	20	14	0.012	0.024	0.010
Nov	66	22	21	0.018	0.010	0.008
Dec	29	14	14	0.012	0.002	0.015
Jan 79	34	---	---	0.021	---	0.017
Feb	41	28	2	0.021	0.025	0.017
Mar	70	19	13	0.009	---	0.017
Apr	79	15	9	0.006	0.015	0.027
May	95	20	20	0.005	---	0.037
Jun	105	20	36	0.004	---	0.037
Jul	108	13	43	0.010	---	0.035
Aug	121	14	37	0.009	0.012	0.031
Sep	137	22	58	---	0.017	0.021
Oct	71	18	34	---	0.018	0.015
Nov	73	15	32	---	0.018	0.015
Dec	86	12	42	0.009	0.027	0.014
Jan 80	57	18	17	0.014	0.018	0.017
Feb	52	12	12	0.011	0.018	0.015
Mar	66	24	34	0.009	0.009	0.015
Apr	103	14	39	0.009	0.010	0.020
May	109	10	33	0.007	0.009	0.021

⁺Values in micrograms per cubic meter

*Values in parts per million

Missoula

The elevation of the Missoula area is approximately 3200 feet above sea level. The city of Missoula is located in the center of two large valleys, which have a major influence on local meteorological conditions. The Continental Divide, 70 miles east of Missoula, and the Bitterroot Range, 20 miles southwest, significantly influence the area's meteorology. During the cooler months, the area experiences frequent temperature inversions that tend to elevate concentrations of trapped pollutants.

The major industrial activities in the area are wood-product related; a pulp and paper mill, two plywood plants, a particle board plant, and a number of sawmills all contribute to the area's air pollution situation. Automobiles and home heating devices are also a growing concern because of heavy traffic and the great number of homes now using wood-burning stoves and fireplaces. Air pollution monitors are shown in Figure 4.

Table 7 lists air quality levels measured at the major MAPS air monitoring station located at Lions' Park in a residential area of central Missoula. Total suspended particulate concentrations in Missoula exceeded the federal and Montana standards. Monthly average concentrations revealed a trend of highest levels during the winter and early spring and lowest levels during the summer.

Although no federal or Montana standard has been adopted, inhalable particulate data were collected at several locations in the Missoula area. Generally, the fine fraction of inhalable particulates showed highest values in late autumn and early winter and lowest values in the summer. The coarse fraction concentration did not reveal a seasonal trend.

Figure 4

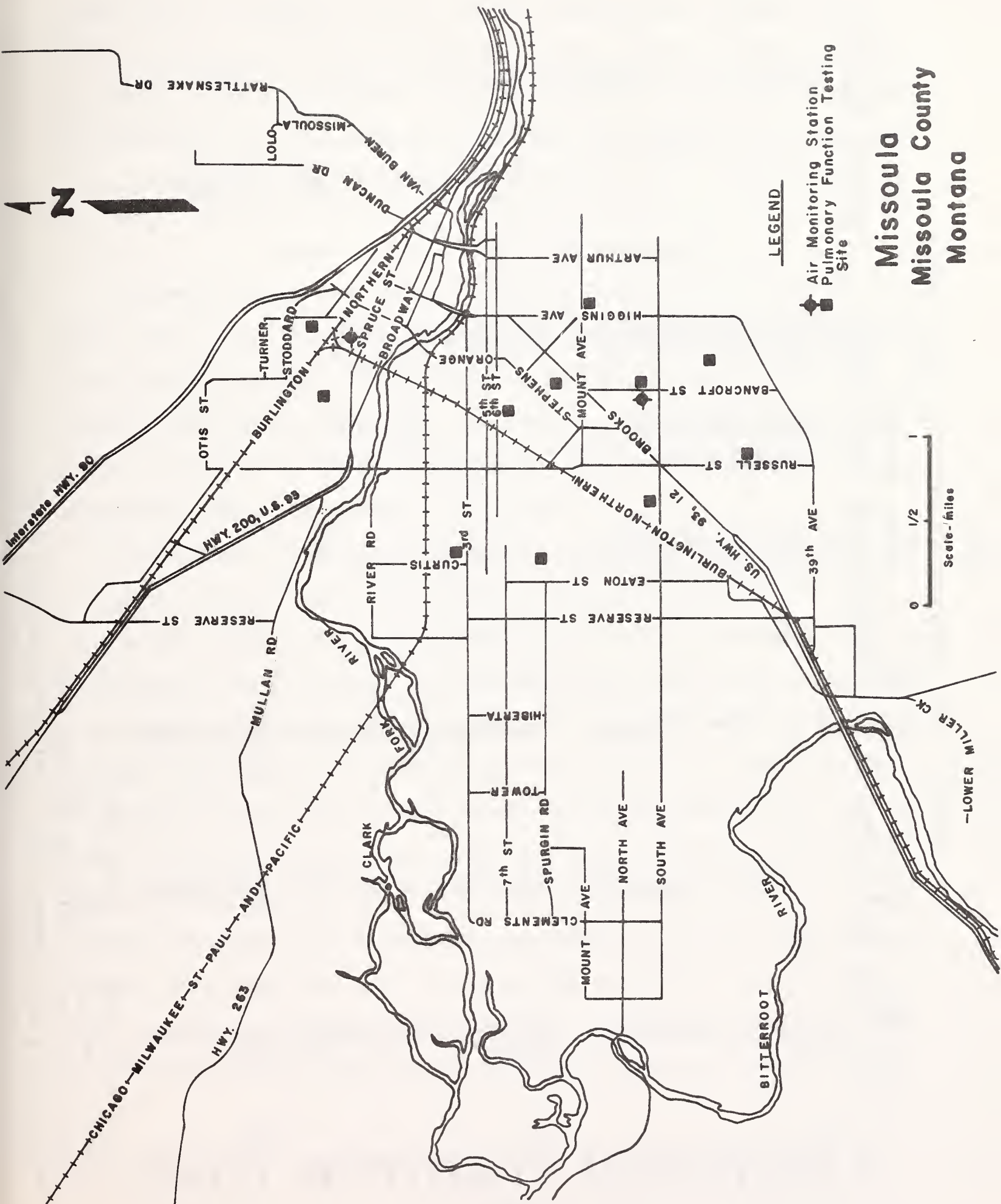


TABLE 7

MISSOULA (LIONS' PARK) MONTHLY AVERAGE AIR QUALITY SUMMARY

Month	Total Susp. Particulates*	Susp. Part. ≤2.5 microns*	Susp. Part. 2.5 to 15 microns*	Sulfur Dioxide†	Nitrogen Dioxide†	Ozone†	Carbon Monoxide†	Beta Scattera	Susp. Parti.
Jan 78	116	---	---	0.00	0.023	0.006	8.2	31	---
Feb	169	---	---	0.00	0.027	0.012	---	33	---
Mar	226	---	---	0.00	0.017	0.021	1.9	20	---
Apr	76	---	---	0.00	0.015	0.017	1.2	7	---
May	61	---	---	0.00	0.013	0.022	---	7	---
Jun	76	---	---	0.00	0.010	0.023	---	7	31
Jul	65	---	---	0.00	0.011	0.023	---	7	39
Aug	69	---	---	0.00	0.012	0.022	---	8	50
Sep	70	18	32	0.00	0.014	0.016	---	9	40
Oct	118	27	42	0.00	0.021	0.015	---	18	79
Nov	93	30	21	---	---	0.010	---	39	78
Dec	71	28	8	---	---	0.008	---	31	57
Jan 79	108	55	2	---	---	0.004	5.6	61	93
Feb	104	50	39	---	---	0.010	3.6	38	86
Mar	170	29	79	---	---	0.018	2.3	25	117
Apr	83	10	33	---	---	0.025	1.3	---	57
May	75	12	41	---	---	0.019	1.1	---	51
Jun	72	13	38	---	---	---	0.8	---	47
Jul	74	12	32	0.014	0.014	0.028	---	---	52
Aug	69	18	26	---	---	---	---	---	48
Sep	94	20	29	---	0.021	0.013	---	11	68
Oct	96	45	24	---	0.026	0.009	---	14	91
Nov	125	50	26	---	---	---	3.4	---	---
Dec	130	39	33	---	---	---	3.8	---	---
Jan 80	135	60	34	---	---	---	2.5	41	36
Feb	202	31	48	---	---	---	2.7	39	---
Mar	105	22	59	---	---	---	0.8	18	---
Apr	---	12	38	---	---	---	2.6	---	---
May	68	14	46	---	---	---	---	---	---
Jun	---	11	32	---	---	---	---	---	---

*Values in micrograms per cubic meter

+Values in parts per million

aValues in scattering coefficient per meter x 105

bMeasured by a beta counter, values in micrograms per cubic meter

Trace element data revealed low concentrations of all elements analyzed, except sulfates. Measured gaseous pollutant concentrations revealed carbon monoxide concentrations below the federal primary one-hour standard but above the federal eight-hour standard. The concentration of carbon monoxide exceeded both the Montana one- and eight-hour standards. The remaining pollutants were below all federal and Montana standards.

Columbia Falls/Hardin/East Helena/Colstrip

This section summarizes ambient air quality data collected in the Columbia Falls, Hardin, East Helena, and Colstrip (coal development) areas. Since these areas received less intensive monitoring under MAPS than the more populated areas of Anaconda, Billings, Butte, and Missoula, the air quality levels in these four areas are discussed collectively. Data on total suspended particulates and sulfur dioxide are discussed.

Columbia Falls is located at the northeastern end of the Flathead Valley in northwestern Montana. The area's elevation varies from less than 2000 feet to more than 10,000 feet in the surrounding mountains. The terrain varies from low elevation, fertile valleys to alpine wilderness, and the climate varies with the elevation and the terrain. The centers of population, mostly in the larger valleys, tend to have milder climates than most areas of the state. Sources of air pollution at Columbia Falls include the Anaconda Aluminum Plant and several wood-products enterprises. Dust produced by automobile traffic and agricultural operations are also significant air pollution sources.

The Hardin area, located in southcentral Montana, is on the western edge of the coal development area. The area is generally rolling terrain and river breaks caused by the Big Horn River. Hardin is located east and north of most of the higher mountain ranges, so the temperature inversions characteristic

of the western Montana valleys are not as evident in Hardin, although air stagnation episodes do occur when high pressure cells form over the area during the winter.

East Helena, located approximately three miles east of Helena in the west-central portion of Montana, is a rapidly growing area with significant subdivision development. The area is about 4000 feet above sea level in the Helena Valley. The surrounding mountains influence the climate as in other western valleys, although the Helena Valley is located east of the Continental Divide. Major industrial activity includes a lead-zinc smelter, a cement plant, and an asphalt plant. The smelter is a source of sulfur dioxide, particulates, and carbon monoxide, while the other activities are primarily sources of particulates. Urban growth in the area, agricultural operations, and unpaved roads are also significant sources of particulates.

Colstrip and Hardin, located in southeastern Montana, are in the center of a major coal development region that is composed essentially of rolling plains with some smaller mountains and buttes. The climate is harsh with long, cold winters and hot, dry summers. Industries include agriculture, timber production, and coal development, that together with unpaved roads produce particulate emissions.

Table 8 lists ambient particulate levels measured at Columbia Falls, Hardin, East Helena, and Colstrip, while Table 9 shows sulfur dioxide measured only at East Helena. The data show that total suspended particulate concentrations exceeded federal and state standards at Columbia Falls, Kalispell, Ronan, and East Helena. The highest concentrations generally were measured in the early autumn, while the lowest were observed in the late winter or spring. Sulfur dioxide (SO₂) measurements from East Helena showed concentrations to be at or below all federal and Montana standards.

TABLE 8
COLUMBIA FALLS/HARDIN/EAST HELENA/COLSTRIP AREA PARTICULATE SUMMARY
(Values in Micrograms Per Cubic Meter)

SITE	MAXIMUM READINGS			APITHMETIC		GEOMETRIC		NO. OF Observ.	TIME Period
	High	2nd High	3rd High	Mean	Std. Dev.	Mean	Std. Dev.		
Polson, Lake Co.	202	191	188	72	55	55	2.2	64	Feb.79-June80
Anders Columbia Falls	484	426	423	130	95	96	2.2	147	Jan.78-June80
N. of Anaconda Alum. Columbia Falls	64	60	59	26	15	22	2.0	146	Jan.78-June80
Strom, Kalispell	343	289	208	88	54	79	2.2	64	Oct.78-May80
Universal Athletic Kalispell	197	192	141	97	47	87	1.6	18	Jan.80-June80
Ronan, Lake County	406	311	288	97	76	69	2.3	80	Nov.78-June80
Warren Ranch, Hardin	135	113	100	27	25	18	2.5	86	Jan.78-Feb.80
Thomas Ranch, Decker	209	139	134	49	32	41	1.8	97	Jan.78-June78 Jan.79-June80
A & W, E. Helena	329	158	138	80	59	67	1.7	27	Dec.79-June80
Hastie Res. East Helena	349	346	324	95	52	82	1.7	142	Jan.78-June80
BN, Colstrip	174	165	138	46	44	29	3.0	45	June78-Sep.79
Randall Ranch Broadus	56	51	48	23	14	18	2.2	30	Jan.78-Sep.78

TABLE 9

EAST HELENA AREA SULFUR DIOXIDE DATA SUMMARY
(Values in Parts Per Million)

AVERAGING TIME -----	EAST STACK (Jan.78-May79,Oct.79-Nov.79) -----	BROUDY (Jan.78-Feb.80) -----	A & W (Nov.79-June80) -----
1-hour max. (high)	0.48	0.80	0.26
1-hour max. (2nd high)	0.34	0.49	0.20
3-hour max. (high)	0.25	0.41	0.19
3-hour max. (2nd high)	0.21	0.27	0.14
24-hour max. (high)+	0.08	0.11	0.04
24-hour max. (2nd high)	0.05	0.10	0.03
Average*	0.006	0.004	0.008
No. of readings	8,923	15,294	3,728

*Time period of average varies by site

+Midnight to midnight

Three Valley Meteorological Dispersion Studies

The Montana Air Quality Bureau, under the auspices of the Montana Air Pollution Study and in cooperation with the Anaconda Company and Champion International Corporation (formerly Hoerner-Waldorf), conducted extensive meteorological studies of the Deer Lodge and Missoula Valleys, respectively. MAPS conducted a similar study in the Yellowstone River Valley. Data were obtained on mixing heights, atmospheric stability, and on the height, intensity, and duration of inversions, as well as other related meteorological parameters, in order to assess the influence of the three valleys' respective topography on air pollution dispersion. This section briefly summarizes the results of the three dispersion studies.

Deer Lodge Valley Dispersion Study

The Deer Lodge Valley Dispersion Study was conducted from May 1978 through December 1979, and results of the study are presented in two technical reports issued in July 1979 (Harner et al.) and October 1980 (Nelson et al.). The study arose from the need to characterize the area around the Anaconda Company's large copper smelter at Anaconda, Montana, in order to provide the data necessary for air pollution modeling and to identify meteorological conditions associated with high SO₂ concentrations that can be hazardous to human health, property, and the natural environment. The Anaconda Company's copper smelter is located at the southern end of the Deer Lodge Valley in southwestern Montana, near the city of Anaconda. The valley is about 50 kilometers long, north to south, and 17 kilometers wide, east to west, while the mountain relief to the east of the valley is about 900 meters, and to the west and south about 1500 meters. The smelter's 178-meter (585-foot) stack is located on a hill rising 214 meters (700 feet) above the valley floor. The valley's population is about 15,000.

Various topographic features affect the area's meteorology. The mountainous character of the area promotes frequent valley temperature inversions, which trap air pollutants for short periods and infrequently for extended periods. Several wind drainages can be found in the area, including the Mill Creek Valley, the Warm Springs Creek Valley, and the Deer Lodge Valley. These three wind drainages intersect near the smelter and result in complex wind patterns.

The general climatology of the Anaconda area is typical of the northern Rocky Mountain region. The average annual temperature is 5.8°C (42.4°F). January, the coldest month, averages -5.4°C (22.3°F), while July, the warmest month, averages 18.7°C (65.6°F). The annual precipitation in Anaconda is 364 mm (14.32 inches). February is the driest month averaging 16 mm (0.63 inches), while June is the wettest at 69.5 mm (2.74 inches) (NOAA 1973).

Meteorological data were collected at two sites, one at Highway Junction located at the intersection of U.S. 10A and Montana 48, and one at Lincoln School situated to the west of downtown Anaconda. Data on surface wind direction collected at the two sites indicate that prevailing winds in the valley are southwesterly. A comparison of the monthly average wind directions reveals that the winds measured at Lincoln School are consistently more westerly than those winds measured at Highway Junction. This phenomenon is most likely due to westerly drainage winds from the Warm Springs Creek Valley, which are most noticeable during the summer.

Data on surface wind speed collected at Lincoln School and Highway Junction show a very sharp variation in average wind velocity at each station. Highway Junction wind velocities average between two and eighteen times greater than those found at Lincoln School for any given month. The lower wind velocities at Lincoln School probably are due to the station's particular location in the

Warm Springs Creek Valley, which protects the site, in contrast to the location of the Highway Junction site in a broad flat portion of the Deer Lodge Valley. The low wind velocities at Lincoln School denote the probability that stagnant air can settle into the area, resulting in air pollution accumulation due to a lack of atmospheric mixing and dispersion. The relatively high mean and maximum wind velocities at Highway Junction tend to eliminate high pollution concentrations due to stagnation.

The strongest morning inversions occur during the summer and autumn, with the weakest during the spring. Autumn and winter have the strongest afternoon inversions, and summer the weakest. In relation to possible effects of inversions on pollution dispersion in the Anaconda area, it appears that the fall and winter are most conducive to pollution accumulation below inversions. This conclusion is due to the findings that in general summer inversions lift to high levels and/or dissipate during the day. In contrast, fall inversions tend to remain intact and undergo less change in strength than summer inversions.

In general, stable conditions form earliest during the evening in the winter and latest during the evening in the summer. Stable condition breakup occurs earliest during the summer and latest during the winter, while the stable layer lift rate is greatest in the summer and least in the winter. Stable conditions are longest in duration during winter and shortest during summer. The implications for air stagnation and the resulting possibility of pollution augmentation are apparent. The winter atmosphere is stable one-third of the day longer than the summer atmosphere, and winter experiences sulfur dioxide readings that are 22 percent higher than in summer. This positive correlation between stable period duration and high sulfur dioxide measurements indicates a possible

relationship between these two parameters. The correlation also holds for a winter-autumn comparison but breaks down for a winter-spring comparison. One can hypothesize that erratic spring winds and frequent storm fronts cause the spring deviation.

Several case studies described by Harner (1979) and Nelson (1980) were conducted to assess the meteorological conditions that cause ground-level SO_2 concentrations from the Anaconda Company's copper smelter to exceed state and federal ambient air quality standards. The Anaconda smelter discharges SO_2 from three primary sources; i.e., the furnace and converter rooms, the acid plant, and the main stack. The SO_2 originates in a building that houses the electric furnaces and converters, where copper ore concentrate is subjected to a thermal reduction process that produces SO_2 as a byproduct. Pollutant trapping systems are not totally effective on these sources, as some SO_2 escapes from the buildings into the atmosphere. Pollutants captured in the furnace and converter rooms travel through the balloon flue network into either the main flue or the baghouse. (The old main flue is seldom used.) Upon entering the baghouse, most of the particulate matter is separated from the gases. A regulated amount of these gases then is diverted to the acid plant, where most of the SO_2 is converted into sulfuric acid. The remainder is emitted from the acid plant stack. Gases not diverted from the baghouse to the acid plant pass through a flue into the main stack, which is the third and largest source of SO_2 emissions.

The various case studies indicate that the complex topography and corresponding meteorology around the Anaconda smelter cause SO_2 concentrations to accumulate at Highway Junction and in Anaconda. Strong southwesterly winds induce a downwash condition behind the smelter's main stack, which forces the stack's plume to the ground near Highway Junction. Frequent inversions in the Deer Lodge Valley tend to trap SO_2 accumulations at ground level. At Lincoln

School in Anaconda, high SO₂ measurements are associated primarily with air stagnation and atmospheric temperature inversions. A secondary factor is the presence of light westerly winds that are not strong enough to disperse air pollutants from the area.

Missoula Valley Dispersion Study

The Missoula Valley Dispersion Study was conducted from May 1978 through November 1979, and results of the study are presented in a technical report issued in September 1980 (Middlemist et al.). The study arose from the need to assess the influence of mountain-valley terrain on the meteorology of the Missoula Valley, a bowl-shaped area in western Montana consisting of a portion of the Bitterroot Valley to the south, and the Clark Fork Valley to the west-northwest. As a result of its topography, the Missoula Valley experiences frequent climatic temperature inversions during late fall and winter, which prevent the dispersion of air pollutants from the area. The city of Missoula and the University of Montana are located in the valley. In order to characterize the valley's meteorology, the Air Quality Bureau and Champion International Corporation (formerly Hoerner-Waldorf) established a comprehensive meteorological network consisting of seven sites located throughout the Missoula Valley. Meteorological data were also obtained from the National Weather Service (NWS) and from the U.S. Forest Service's Northern Forest Fire Laboratory west of Missoula.

Results of the study indicate that the air circulation pattern in the Missoula Valley as it relates to air quality and pollution characteristics is complicated by the terrain, which creates low-level wind patterns that vary significantly not only from one portion of the valley to another, but also from day to night. During the night and early morning hours, the Missoula Valley

represents an area of confluent winds. During the day, when surface heating causes air currents to rise, confluent winds favor upward vertical motion, although at night, they often hold atmospheric air pollution in the valley areas, as cool, dense air remains close to the ground.

The lowest average monthly wind speed occurs in autumn and winter. With the exception of the University of Montana (UM) site, the highest average monthly wind speed occurs in the spring. The lowest average hourly wind speed generally occurs in the early morning hours when vertical mixing of air is at a minimum; the highest average hourly wind speed can be found during the afternoon hours when vertical mixing is at a maximum due to surface heating.

The prevailing wind direction is dependent on location in the Missoula Valley. (All meteorological sites except the UM site were placed in relatively open areas. The UM site, located at the mouth of Hellgate Canyon, experienced very little cross-wind flow.) In general, however, the average wind direction for the Missoula Valley is south-southwest for all seasons.

During the spring and summer, the Missoula Valley experiences a diurnal pattern of inversions; i.e., due to radiational cooling during the night, an inversion exists in the early morning hours and dissipates during the day. During the autumn and winter, however, the valley experiences extreme inversion situations that may persist for several days. A seasonal comparison indicated that an inversion was present in 99 percent of all morning observations. For afternoon observations, the autumn and winter experienced inversions at least 92 percent of the time, and summer experienced them at least 64 percent of the time. The spring had 26 percent surface-based morning inversions, while the winter had 12 percent. The winter and spring experienced 4 percent or less

surface-based afternoon inversions, while the summer and autumn experienced no afternoon surface-based inversions. In summary, for all seasons, the mornings experience more total and surface-based inversions than the afternoons. Except for the autumn, morning inversions have a lower inversion base height and greater inversion thickness than afternoon inversions.

In conclusion, it can be stated that meteorological conditions in the Missoula Valley strongly influence the frequency and severity of ambient air pollution concentrations in the valley. The ability of the lower atmosphere to disperse, to dilute, and to mix pollutants released into it varies immensely with daily, weekly, or seasonal meteorological fluctuations. Therefore, only through joint analysis of ambient air quality and meteorological data is it possible to describe, to anticipate, or to predict accurately ambient pollution concentrations in the Missoula Valley.

Yellowstone River Valley Dispersion Study

The Yellowstone River Valley Dispersion Study was conducted from August 1978 through May 1980, and results of the study are presented in a technical report issued in February 1981 (Gelhaus). This study arose from the need to characterize the influence of rimrocks and cliffs on the meteorology of the Yellowstone River Valley, which is located in south-central Montana. The city of Billings, Montana's largest urban population center, is surrounded by the valley's cliffs and rimrocks, which cause inversions to form, trapping air pollutants in the area below the cliffs for extended periods of time. Since the majority of industrial activity and population in Billings is situated below the cliffs, the MAPS project concentrated meteorological and air quality monitoring in the area; i.e., at Central Park in west-central Billings. Data on surface

meteorological conditions already were being collected at the National Weather Service (NWS) station in the city's Logan Field Airport, located on top of the adjacent cliffs. Upper air meteorology was monitored at the Vocational, Technical, and Career Placement Center (Vo-Tech) west of Billings.

Results of the study indicate that general wind direction in Billings is westerly, although wind speed is quite low. For example, during the first half of 1980, calm winds occurred more than 25 percent of the hours monitored. Likewise, the percentage of hours having wind speeds less than 1.5 meters/second was very high in 1980. Slow wind speeds in the Billings area are very relevant to air pollution considerations, because higher wind speeds tend to "cleanse" an area of air pollution by diluting and transporting the pollution downwind. In contrast, air pollutants tend to accumulate or to stagnate with slow wind speeds.

Analysis of data on inversion base height, thickness, and strength shows that inversions are present almost every morning in Billings. Most of these inversions are surface-based, 100-250 meters thick. Very few surface inversions are more than 500 meters thick. Afternoons in Billings experience fewer inversions than the mornings. Moreover, afternoons experience a pronounced seasonal variation, as the least number of surface-based inversions occur during the summer, while most occur during the winter. The greater frequency of inversions during the winter rather than the summer is a result of less intensive solar radiation during the winter.

In conclusion, the Yellowstone River Valley, which is situated southwest through northeast and averages 20 kilometers wide and 100 meters deep, plays an important role with regard to air pollution dispersion in the Billings area. Frequent calm or near calm wind speeds and surface-based inversions also tend to stagnate air pollution emissions in the area.

CHAPTER III

EMISSION INVENTORY ACTIVITIES

An emission inventory is best described by defining the concept's two components. In an air quality context, an emission is a liquid, solid, or gas released into the atmosphere from an air pollutant source. Since an inventory is an itemized list of the type and quantity of available materials, an emission inventory lists the amount and type of air pollutants released into a particular area during a specific time period.

Traditionally, emission inventories have been based upon annual totals of pollutants emitted from various sources. Such inventories usually have been created through different mechanisms corresponding to the two major classifications of emission sources; i.e., point and area. (A point source is a single large stationary source, such as a refinery, smelter, sawmill, or paper mill. Area sources, on the contrary, are small, dispersed pollution sources, which do not lend themselves well to individual analysis; these include mobile sources, such as automobiles, and stationary sources, such as residential heating units and fugitive dust.)

Emission inventories are sources of information with multiple uses, including environmental planning, development of pollution control strategies, and enforcement. An accurate emission inventory, in combination with meteorological data and a dispersion model, also can be used to estimate present and future air pollution levels within a given area. The emission inventory activities conducted under the Montana Air Pollution Study included a basic

inventory designed to include several unique features not usually included in such inventories, and a feasibility analysis with respect to historical emissions. The Air Quality Bureau's Robert Raisch served as Project Officer of the emission inventory area.

Update and Improvement of the Emission Inventory

Prior to the commencement of MAPS, the Air Quality Bureau's emission inventory was outdated for many areas of Montana. In addition, the inventory included only five major pollutants (sulfur dioxide, total suspended particulates, carbon monoxide, hydrocarbons, and nitrogen oxides) and was on an annual basis, which is typical of traditional emission inventories.

During the MAPS project's initial planning stages, the staff concluded that the existing inventory was inadequate for a health effects study in that other pollutants, such as trace metals (lead, arsenic, and cadmium), sulfates, and respirable particulates should be included in the inventory from a health viewpoint. In addition, the extreme meteorological conditions found in Montana's mountain valleys, combined with emission rates that change over the seasons, required a monthly inventory as opposed to the standard annual inventory. The update and improvement of the emission inventory thereafter was contracted to Midwest Research Institute (MRI) of Kansas City, Missouri, a major environmental research firm. MRI completed the inventory update in November 1979.

MRI personnel reviewed Montana's existing emission inventory and spent considerable time in the state cooperating with Air Quality Bureau and local air pollution agency personnel to develop localized emission factors applicable to Montana. MRI personnel conducted extensive sampling of surface materials from paved and unpaved roads, agricultural soil, industrial tailings, slag heaps, copper mining haul roads, and refinery coke from the study areas of Deer Lodge,

Missoula, Silver Bow, and Yellowstone Counties. The samples were analyzed for particle size, density, and trace metals, and the results in turn were used to calculate road surface dust loadings and other emission data. MRI also conducted a literature review to determine the best available emission factors for Montana's specific air pollution sources.

Results

This section summarizes the results of MRI's effort to update and to improve the emission inventory in the four study counties in terms of tabulated emissions estimates. It should be emphasized that the numbers are estimated in such a way as to be comparable for various pollutants, months, or geographical areas. The estimates can be overinterpreted if taken out of context.

Table 10 summarizes the estimated total emissions of the major pollutants considered for the study areas, which were divided into two parts; i.e., city and surrounding area. (In Silver Bow County, the Berkeley Pit was considered to be an additional source area.) Results of the updated emission inventory for the four counties indicate that total hydrocarbons, carbon monoxide, and nitrogen oxides are emitted primarily by motor vehicles in the study areas, as is typical nationally, although in Billings and Yellowstone County, point sources at the refineries also are major contributors of these pollutants. Sulfur dioxide emissions are low in Missoula and Silver Bow Counties, although the refineries in Billings and the smelter in Anaconda emit large quantities of the pollutant. Fugitive dust emissions dominate particulate pollution in all the areas.

Table 11 summarizes similar emission estimates for the other nine inventoried pollutants. Among the metals, lead has a source in automobile traffic, iron and aluminum are found primarily in the natural soil, and the others come from either the soil, other fugitive sources, or mining and smelting operations. Sulfuric acid mist comes primarily from area sources.

TABLE 10
ANNUAL EMISSION ESTIMATES
FOR MAJOR POLLUTANTS

	Estimated Emissions, tons per year				
	Total Particulates	Particulate <2.5 ug/m3	Sulfur Dioxide	Total Hydrocarbons	Carbon Monoxide Nitrogen Oxides
Deer Lodge County					
--Anaconda-----	8,900	4,500	270,000	210	1,500 220
Balance of County	6,600	2,300	70	430	4,200 570
Missoula County					
--Missoula City	31,000	12,000	320	1,900	16,000 2,200
Balance of County	75,000	24,000	1,800	1,900	31,000 3,500
Silver Bow County					
--Butte-----	11,000	4,200	100	950	6,600 990
Berkeley Pit	15,000	6,000	290	300	800 3,700
Balance of County	9,100	3,100	85	500	4,300 740
Yellowstone County					
--Billings-----	42,000	16,000	33,000	6,200	86,000 12,000
Balance of County	13,000	41,000	7,800	2,800	15,000 2,900

Table 11
ANNUAL EMISSION ESTIMATES
FOR MINOR POLLUTANTS

	Estimated Emissions, tons per year									
	Lead	Arsenic	Cadmium	Vanadium	Copper	Iron	Aluminum	Zinc	H ₂ SO ₄	
Deer Lodge County	140	240	6.7	2.0	420	640	1200	130	4.7	
Anaconda City	3.2	0.13	0.04	1.4	4.5	200	430	7.1	9.9	
Balance of County										
Missoula County	15	0.07	0.15	2.8	11	580	1400	5.4	66	
Missoula City	8.9	0.19	0.11	7.4	20	1100	2800	6.9	32	
Balance of County										
Silver Bow County	6.8	0.32	0.06	2.0	9.7	200	940	13	28	
Butte City	9.1	1.4	0.32	2.3	57	410	1000	44	0	
Berkeley Pit	3.5	0.17	0.06	1.6	5.1	290	630	7.6	10	
Balance of County										
Yellowstone County	38	0.11	0.14	4.7	6.9	1200	2400	7.0	110	
Billings City	3.7	0.62	0.45	13	34	3000	8100	15	36	
Balance of County										

The emission estimates made by MRI can be tabulated in several ways for various purposes. Further summaries are presented in MRI's final report, which is available upon request from the Air Quality Bureau.

Feasibility Study - Historical Emission Inventory

Because of the long incubation period (twenty to thirty years) usually required to develop chronic respiratory diseases, the MAPS staff felt that an attempt should be made to estimate emissions from a historical perspective. Since industrial processes, automobile usage, and fuel use patterns have changed markedly over the decades, emission and ambient air pollution levels certainly have changed as well. The concept of emission inventories developed only in the 1960s, so it was unclear whether a historical emission inventory could be created. Consequently, the MAPS staff decided to assess data availability through a feasibility study in the Butte-Anaconda area, which was selected because of its extensive industrial activity and general historical records of that activity.

In January 1978, the Bureau signed an agreement with Historical Research Associates (HRA) of Missoula to perform a six-month feasibility study to determine whether data existed to provide reliable historical emission estimates for the period 1880 to the present. HRA examined many diverse sources of information, including the Montana Historical Society, the University of Montana archives, the Montana School of Mineral Science and Technology library, personal interviews, and local industries. Information on the following was sought:

A. Industrial and commercial activity:

1. nature of process and equipment used;
2. location within area and period of operation;
3. production levels or quantities of materials processed;
4. emission levels or estimated emission levels; and

D. Domestic activity:

1. nature of fuels used for home space heating, cooking, and lighting;
2. types of devices using above and quantities of fuels consumed;
3. methods of transportation used, i.e., number of motor vehicles and miles of paved and unpaved roads;
4. historical population shifts within the Butte and Anaconda urban areas.

Results

HRA found extensive information that could be used to develop a historical emission inventory of the Butte-Anaconda area. Because Butte was a world leader in mining and metallurgy, particularly of copper, extensive information was found on those subjects. (HRA researchers photocopied this information, which is available at the Air Quality Bureau.) In contrast to the information on mining and metallurgy, HRA found little information on nonindustrial sources of air pollution. Annual statistics for population and vehicles in the Butte-Anaconda area were located, but only sketchy historical information was available on street paving, home heating, and residential lighting.

With the completion of HRA's initial information search, the Bureau contracted with MRI to cooperate with HRA to provide a technical review of the findings and to recommend whether further research was warranted. On 31 August 1978 MRI submitted a report recommending:

1. that a historical inventory be completed for ten-year periods starting in 1880 and ending in 1970;
2. that the inventoried pollutants include total suspended particulate, sulfur dioxide, lead, arsenic, cadmium, and copper;
3. that all significant sources of the pollutants be inventoried; and

4. that the historical emission inventory be completed jointly between MRI and HRA, with HRA providing a historical review of the Butte-Anaconda area with respect to industrial development, and MRI providing appropriate emission factors.

The Bureau provided both the HRA report on information availability and the MRI report on inventory feasibility to the Emission Inventory Advisory Committee, and requested comments and recommendations. Although the committee indicated that the concept of a historical emission inventory had significant merit, serious concern existed as to cost and potential inaccuracies. Consequently, the majority of committee members recommended against further work. The Bureau evaluated the reports and recommendations and decided to terminate the project.

CHAPTER IV

PULMONARY FUNCTION TESTING

The largest health effects component conducted under the Montana Air Pollution Study was extensive pulmonary function testing among elementary school children in five principal Montana cities and among Missoula adults with chronic obstructive pulmonary disease (COPD). Results of this testing are presented in three technical reports issued by the Air Quality Bureau: 1) "Pulmonary Function Testing of Elementary School Children" (October 1979); 2) "Pulmonary Function Testing of Patients with Chronic Obstructive Pulmonary Disease" (September 1979); and 3) "Relationship Between Human Health and Inhalable Particulates" (October 1980). This section of the MAPS final report summarizes the findings stated in these three reports.

Study Design

The lung is the organ most likely to be affected by air pollution. A normal adult at rest inhales and exhales approximately six liters of air per minute. Therefore, during a twenty-four hour period or a lifetime, the lung may be exposed to large amounts of foreign substances in the air. Over a long period of time, or sometimes over only short periods, these substances inhaled into the lung can impair the basic physiological functioning of the lung. Consequently, the measurement of lung function, or pulmonary function testing, is a standard approach used to assess the effects of air pollution on human health, and was adopted as the principal health effects component of MAPS.

Because many subjects were to be screened from widely separated geographical areas during a relatively short time, and because trained personnel time is relatively costly, it was decided not to use conventional water spirometry with individually read graphs. Instead, the Jones Pulmonor, with a datamatic microprocessor printout was used to measure pulmonary function. This machine was easily portable, provided both a mechanically traced graph and an automated microprocessor printout of each test, could be operated and interpreted without prolonged training, and rapidly tested a large number of subjects. The Jones Pulmonor measured the following lung parameters during the course of the MAPS pulmonary function testing program:

Forced Vital Capacity (FVC): The total amount of air breathed out; FVC represents the lung volume used in breathing. This parameter is closely related to the subjects' size and stage of growth and is not expected to vary dramatically over a short period of time.

Forced Expiratory Volume (FEV₁ and FEV₇₅): The volume of air expired during a certain initial period of time. MAPS recorded two such parameters: FEV in one second, i.e., the amount of air expelled in the first second; and FEV₇₅, the amount in the first three-quarters of a second.

Forced Expiratory Flow Rate (FEF 25-75): This parameter measures the speed or rate at which the air can be expelled, which in turn reflects the airflow resistance of the lungs medium- and small-sized air passages. This airways resistance is highly dependent upon inflammatory or structural changes due to infection, allergy, or other insults such as air pollution, and hence would be expected to reflect short-term, acute effects. The parameter is calculated as the average flow rate for the middle half of the air moved; i.e., between the 25 percent point and the 75 percent point.

Peak Expiratory Flow Rate (PEFR): This is the single highest flow rate; that is, the steepest slope of the curve on the chart. Usually this occurs at the beginning of expiration, reflecting the effort required to move static volumes of air through the large airways.

Communities/Elementary School Children

The Montana Department of Health recommended that the 1977 Montana Legislature fund a major study of the health effects of air pollution in the communities of Anaconda, Billings, Butte, and Missoula. As a result, the Legislature mandated and funded the subsequent Montana Air Pollution Study (MAPS). Great Falls was selected by the MAPS Health Effects Advisory Committee (see Appendix A-1) for inclusion in the pulmonary function study as a comparison community with relatively clean air. Missoula was selected for more intensive study, because its citizens and medical community are very concerned about air pollution, which assured good cooperation, and because the principal investigator, Dr. Kit G. Johnson, lives there. This proximity reduced the cost and provided better supervision for implementation of the MAPS project.

Extensive pulmonary function testing of elementary school children was conducted in Anaconda, Billings, Butte, Great Falls, and Missoula, while a smaller effort was made in Hardin and Crow Agency in the Colstrip-Hardin area. The school boards in Colstrip and East Helena, which the 1977 Legislature added to the study, refused to participate. The Billings School Board also refused to allow Billings public school children to be tested, so MAPS included 139 children from four urban parochial schools in the study. Moreover, 171 children from the Billings suburban area of Lockwood were studied. (The only significant demographic differences between the Billings parochial and Lockwood children were in the educational and occupational levels of the parents. However, the two groups were combined in the analysis of cross-community data, and as a whole did not have significant socio-economic differences from the other communities studied.) The Air Quality Bureau believed that Lockwood had air pollution problems similar to those of Billings because of the refineries' location and the prevailing wind patterns.

Third-, fourth-, and fifth-grade children were chosen for testing in this component of MAPS on the recommendation of the project's principal consultant, Dr. Benjamin Ferris of Harvard University, because they were old enough to cooperate but too young to begin heavy smoking. During the study, each child was asked privately whether he or she had ever smoked, and less than 0.5 percent said they had smoked more than five cigarettes.

During the winter of 1977, the pulmonary function testing program was initiated to test Missoula children monthly through the spring of 1978. In order to provide data from areas with cleaner air for comparison with the Missoula data, Great Falls children were tested once in May 1978, while children from two Missoula suburban schools also were tested once; i.e., those from Target Range in January and those from Clinton in February 1978.

During the 1978-79 school year, third- and fourth-grade children from Anaconda, Billings (parochial and Lockwood), Butte, Great Falls, and Missoula were tested once in the fall, once in the winter, and once in the spring in order to provide a seasonal comparison of pulmonary function measurements on a cross-community basis. In addition, another group of Missoula fourth- and fifth-grade children tested in 1977-78 as third- and fourth-graders was retested monthly during the 1978-79 and 1979-80 school years to provide data on the acute effects of air pollution exposure.

Adults

During 1977-78, Missoula adults with chronic obstructive pulmonary disease (COPD), which includes emphysema, chronic bronchitis, and asthma, were given pulmonary function tests to determine whether their pulmonary function ability deteriorated when ambient air pollution concentrations rose. (COPD patients are thought to have increased reactivity to air pollution.) Testing of the COPD patients began 7 January 1978. The COPD study was designed to test 80

to 100 persons each month. Thus, 20 to 25 persons could be tested each week to provide a continuous time coverage without demanding excessive effort from the persons tested. The patients also kept a diary of pulmonary symptoms, self-medication, and activities for the seven-day period prior to their monthly pulmonary function test.

Anticipating subject attrition, the MAPS project originally sought a test group of more than 100 persons, and efforts to obtain additional participants were maintained throughout the test period. The following criteria had to be met by each subject in the study:

1. Diagnosed for chronic obstructive pulmonary disease, preferably confirmed by an abnormal pulmonary function test;
2. Not smoking and willing not to smoke for the duration of the study;
3. Ambulatory and performing normal employment or homemaking tasks;
4. Not subject to unusual occupational air pollution exposure; and
5. Living in the urban Missoula airshed.

The COPD study relied heavily on excellent cooperation from a sizeable number of volunteers over a long period of time, a degree of volunteer effort that researchers commonly regard as difficult to obtain. Consequently, the COPD patient study was pilot-tested in Missoula, where a high level of environmental concern was expected to provide the best chance for success. In May 1978, it was decided to limit the COPD study to Missoula until enough data could be analyzed to determine if the results were sufficiently significant to warrant the increased expenditure of conducting the COPD study in other study cities.

As anticipated, there was subject attrition. Of the nearly 100 original participants, 13 withdrew after only one test. Of those remaining, 31 left the study during the subsequent eighteen months. Of these, 17 simply lost interest, 7 moved out of the Missoula area, 4 found they could not stop smoking, and 3 became too ill to participate. Two of the latter died during the study period.

Eighty-four COPD panelists provided some data during the course of the eighteen-month study, and 17 of them provided the maximum amount of data by having their pulmonary ability recorded on eighteen different occasions (roughly monthly). Sixty-eight panelists had at least six periods in which their pulmonary parameters were measured, and it was these individuals upon whom the statistical analysis of COPD data was based.

Analysis of Confounding Variables

Meteorological Factors

The meteorological factors of outside temperature, humidity, and barometric pressure were analyzed by linear regression as to their influence on Forced Vital Capacity (FVC), Forced Expiratory Volume (FEV₁), and Forced Expiratory Flowrate (FEF₂₅₋₇₅). It was found that none of the meteorological factors accounted for more than 1.5 percent of the variability in a pulmonary parameter. Therefore, it was concluded that the influence of meteorological factors on pulmonary function was too small to warrant further concern.

Altitude

The five major communities of Anaconda, Billings, Butte, Great Falls, and Missoula studied under the MAPS project are located in the northern Rocky Mountains and high plains with an elevation range between 3124 feet (Billings) to 5549 feet (Butte) (952 to 1691 meters). Because of this variation, the normal barometric pressure may be expected to vary from 618 to 678 milliliters of mercury, a difference of 9.7 percent. This difference in barometric pressure can affect pulmonary function tests. Therefore, the principal MAPS statisticians, Drs. Rudy Gideon and Don Loftsgaarden of the Department of Mathematics at the University of Montana in Missoula, adjusted the five cities'

pulmonary function measurements to a sea level standard atmospheric pressure for purposes of comparison after conducting extensive evaluation of the relationship between altitude and the pulmonary parameters.

Socio-Economic and Disease Variables

Doctors Ferris of Harvard University and Ian Higgins of the University of Michigan suggested during the initial analysis of cross-community pulmonary function data from the five study cities that socio-economic variables could possibly account for some of the differences in pulmonary function readings found among the five cities. Dr. Loftsgaarden conducted an independent analysis to determine whether this was indeed the case. The results indicated that more male heads of households with a college degree could be found in Missoula than in the other four study cities. The results of this analysis showed no significant differences in pulmonary ability among the children studied for this socio-economic factor. There were considerably more male heads of households with occupation listed as professional or administrative in Billings and Missoula than in the other three cities. The results of this study showed no significant differences in the children's pulmonary ability for this socio-economic factor. Missoula had considerably more homes where the father was not present, but again the results showed no significant differences between pulmonary function readings for children in these homes and those where the father was present. Homes where the mother's occupation was listed as "housewife" were compared with those where the mother's occupation was something other than housewife. The results again showed very small pulmonary differences between the two groups of children, although the FEF₂₅₋₇₅ readings tended to be lower for the housewife group.

Billings and Missoula had considerably fewer homes with gas as the primary heating fuel and considerably more electrically heated homes than the other

three study cities. Missoula and Anaconda had more homes with wood as the primary heating fuel, although both were less than 6 percent. Wood as a secondary heating fuel was much higher in Missoula than in the other four cities. Billings, Great Falls, and Butte (to a lesser degree) had 10 to 20 percent more homes with gas as the primary cooking fuel, whereas Anaconda and Missoula had a much higher percentage of homes with electricity as the primary cooking fuel. The results showed that children from homes where wood was the primary or secondary heating fuel tended to have lower pulmonary function readings. If gas was the primary heating and/or cooking fuel, the children also tended to have lower pulmonary readings. Children in all electrically heated homes where electricity was the primary cooking fuel tended to have higher pulmonary readings. Some of the differences were significant. All of the cities were better in some areas and worse in others; e.g., Missoula was high in electrical heating and electrical cooking, but it also was high in wood heating.

The only two socio-economic variables that significantly adversely affected pulmonary readings were wood used for primary or secondary heat and gas used for cooking. Nevertheless, the two variables tended to offset each other's impact among the cities. Careful evaluation leads one to conclude that heating and/or cooking fuels were unlikely to account for differences in pulmonary readings among the cities. For example, in Missoula, the good effects of electrical cooking offset the bad effects of wood burning.

No major differences in the incidence rates for measles, bronchitis, pneumonia, croup, or whooping cough among the five cities appeared evident, except that a very low percentage of Great Falls children had had measles. (Measles are not thought to produce chronic pulmonary deficiencies in most children, although they may lead to severe pneumonia followed by chronic bronchitis and bronchiectasis.) Tests were conducted for each of these diseases

by comparing the pulmonary measurements of children who had had the disease with those who had not had the disease. Essentially no differences were found in each case. Children in homes where at least one person smoked also were compared with homes with no smokers. No significant differences were found.

In conclusion, few or no differences in socio-economic variables among the five cities studied in the cross-community comparison were demonstrated.

Height, Weight, and Age Variables

It was found that height is the only necessary covariant needed in the analysis of pulmonary function data, because height sufficiently adjusts for weight and age differences in children relative to pulmonary function ability.

Results

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Cross-Community Comparison, 1978-79

Missoula Compared to Target Range and Clinton, January/February 1978

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In order to aid in the assessment of air pollution's effect on the pulmonary function of Missoula children, the MAPS staff also conducted pulmonary function testing in one small community west of Missoula (Target Range) and one to the east (Clinton). These tests were conducted not only to obtain data for comparison with Missoula's data, but also to provide experience in dealing with school districts other than Missoula's.

In January 1978, 88 third- and fourth-grade children in the Target Range School were given pulmonary function tests. Target Range is a suburban-rural/agricultural school district adjacent to and immediately west of the city school system. Three miles separate the Target Range school district from the closest-tested Missoula urban school district. The Target Range children are drawn from an area roughly two to fifteen miles from the perimeter of the urban airshed, with the population center probably about three to four miles from the perimeter. During 1974-75, levels of total suspended particulate

(TSP) in urban Missoula were considerably higher than those found in Target Range. There is no reason to assume their relative differences have changed. During badly air polluted winter months, Missoula experiences worse air pollution than Target Range, which results from urban emissions being trapped by stagnant air at the small apex of the Missoula Valley. On the other hand, during the summer, the wind disperses urban pollution but blows agricultural dust throughout the valley, affecting both Target Range and urban Missoula.

In February 1978, 45 third-and fourth-grade children in Clinton School were given pulmonary functions tests. Clinton is a rural/sylvan school district serving a very large geographic area in the upper Clark Fork River Valley 15 to 40 miles east of Missoula. The only suspected air pollution comes from home heating in widely scattered homes, road dust, forest slash burning during the early fall and late spring, and Interstate 90, which crosses the Clinton district and the Missoula urban area. Therefore, the Clinton population is thought to be exposed to very low levels of ambient air pollution.

Results showed that with the exception of FEV₁ in Target Range males, the Missoula urban children had poorer pulmonary function measurements than their neighbor peers, who were exposed to less urban air pollution. It is also interesting to note that Missoula urban females had greater reduction in pulmonary function tests associated with air pollution than the males.

Missoula Compared to Great Falls, May 1978

In May 1978, 328 third- and fourth-grade Great Falls students participated in pulmonary function tests to determine how their pulmonary function compared to that of children in more polluted cities. As part of the pilot acute-effects study in Missoula, 548 third- and fourth-grade children there were given monthly pulmonary functions tests, and the data from April-May 1978 were used for comparison with those from Great Falls. In 1978, the geometric mean

annual level of TSP in Great Falls was 42 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), while it was 81 $\mu\text{g}/\text{m}^3$ in Missoula. Analysis of pulmonary function data from the two communities showed that the Missoula children had significantly lower pulmonary function test results than the Great Falls children. The percentage difference was greatest (10.2%) for FEF₂₅₋₇₅, which represents small airways resistance.

Five-Community Study, 1978-79

During the 1978-79 academic year, approximately 300 to 400 children from each community of Anaconda, Billings, Butte, Great Falls, and Missoula were tested once each in the fall, the winter, and the spring. Great Falls was included in this study as a relatively air-pollution free city to provide comparison with the pulmonary function test results of children from more polluted cities. See Table 12 for an overview of air pollution levels found in the five study communities.

TABLE 12
AIR QUALITY CHARACTERISTICS OF
MAPS COMMUNITIES

1978-1979 18 Months Data	Anaconda Lincoln School	Billings Central Park	Butte Hebgen Park	Missoula Lions' Park	Great Falls Kiwanis Park
TSP $\mu\text{g}/\text{m}^3$					
-Average arithmetic	57	88	76	101	43
-No. days >200	3	9	1	37*	0
Dichotomous $\mu\text{g}/\text{m}^3$					
-Total <15					
-Avg.	33.4	36.4	56.6	58.4	33.8
-Max.	74.0	117.0	95.3	181.5	60.7
-Coarse 2.5-15					
-Avg.	19.9	18.7	37.0	34.9	22.9
-Max.	40.3	74.4	75.7	140.3	43.5
-Fine <2.5					
-Avg.	14.5	17.7	19.6	23.5	10.9
-Max.	41.9	55.4	65.9	83.2	28.9
SO ₂ ppm:					
-Average	.033	.011	.008	.000	.000
-No. days >0.14	16	0	0	0	0
NO ₂ ppm:					
-Average	.0063	.0155	.0240	.0172	.0089

*In March 1978 and 1979, twelve days' TSP data were excluded because of excessive windy conditions and street dust.

Seasonal Comparisons of Pulmonary Function Tests

Analysis of seasonal comparisons among pulmonary function tests revealed that the Great Falls children's test results were consistently superior among the five study communities. This finding supports the hypothesis that children in communities with clean air should have better pulmonary function than those from communities with poorer air quality. Furthermore, in all instances, the Great Falls children showed a persistent increase in pulmonary function measurements from one season to the next (fall to winter to spring). Anaconda had a similar pattern, but each of the other communities' children had some instance of deterioration among pulmonary function test results from one season to the next.

It is important to note that height and weight adjustments were done only within seasons, not between seasons. Therefore, as all the children were growing throughout the three seasons, and as essentially the same children were retested in each community each season, their pulmonary function should have increased from fall to winter to spring. It is possible that the failure of Butte and Missoula children to increase their pulmonary function throughout the year was due to an accumulation of air pollution effects over the winter and the early spring. However, to some extent, these effects (if any) must have been reversible during the clean-air seasons of spring, summer, and early fall, as the Butte and Missoula children deviated less from Great Falls children in the fall than they did in the other seasons.

Comparison of Pulmonary Function Tests with Total Suspended Particulate and Respirable Particulate Data

The final aspect of the five-community study pertained to a correlational analysis of the air quality particulate parameters within each community at the time of pulmonary function testing and the overall adjusted averages of FVC, FEV₁, and FEF₂₅₋₇₅. (The adjusted averages imply that each pulmonary average was corrected for the child's height by sex and the community's elevation.

Particulate parameters include average total suspended particulate (TSP), fine respirable particulate levels (≤ 2.5 microns), and total respirable particulate levels (≤ 15 microns). Results showed that in particular Great Falls had three relatively high pulmonary averages, whereas Anaconda had three relatively low pulmonary averages. Overall, all but two of eighteen statistical regressions had negative slopes, which indicates that as particulate levels rise, pulmonary ability falls. A negative correlation between the communities' average particulate levels and the children's average pulmonary function measurements was suggested in the analysis; however, the variables of humidity, quality of particulates, and noxious gases were not taken into account. This suggestion was especially pertinent to Anaconda, where sulfur dioxide levels were high, but particulate levels were not so high.

Summary of the Five-Community Study

The following conclusions can be made with respect to the five-community study. Economic and personal environmental factors were not substantially different among the communities; even the few differences that appeared to affect pulmonary ability tended to cancel themselves because of the way they were spread throughout the communities. During the testing periods, Missoula had the highest particulate levels and Anaconda the highest sulfur dioxide levels, while Great Falls, the comparison city, had the lowest overall air pollution levels. Children's pulmonary ability exhibited strong seasonal variations. Great Falls children performed substantially better on pulmonary function tests than children from the other four communities, and Missoula children performed consistently lower than the other children. Although the Anaconda males tested about average, the Anaconda females were unusually low.

The five communities studied showed statistically significant differences in overall pulmonary function testing ability. When analyzed for pulmonary function versus particulates, sixteen of eighteen statistical regressions had negative slopes, which indicates that lower pulmonary averages occur when particulate levels are high. However, the types of air pollution varied considerably; e.g., Anaconda was the only city with high sulfur dioxide levels, while Missoula had the highest TSP levels. As it stands, it appears that the different air quality levels found in Montana accounted for the differences in pulmonary ability among the communities.

Missoula Acute Effects Study, 1978-79, 1979-80

1978-79

Each Missoula urban area fourth-and fifth-grade child in the acute effects study group was scheduled for pulmonary function testing once in each of eight testing periods in 1978-79 (October, November, December, January, February, March, April, and May). All observations for October and May were excluded to avoid any unusual effects of the first and last tests. All children tested at least three times in the months November through April were included in the analysis.

Each day a child was tested represented one case for that child. As far as this particular study was concerned, the following variables were among those recorded for each case: height; FVC (Forced Vital Capacity); FEV₁ (Forced Expiratory Volume in one second); FEF₂₅₋₇₅ (Forced Expiratory Flowrate); today's TSP (total suspended particulate); yesterday's TSP; three-day average TSP (today, yesterday, and the day before yesterday); today's respirable fine particulate; yesterday's respirable fine particulate; three-day average respirable fine particulate; today's respirable coarse particulate; yesterday's respirable coarse particulate; and three-day average respirable coarse particulate.

Determining the appropriate air pollution time span against which to analyze the children's pulmonary function tests was difficult. Analyzing with today's TSP had a disadvantage as the children were tested early in the morning, but today's TSP value was recorded from midnight to midnight; thus, air pollution may have changed significantly after the children were tested. However, today's air pollution value could not be ignored. On the other hand, it was reasonable to assume that any air pollution effects upon pulmonary function tests may have been accumulative over a short time. Therefore, after a series of preliminary tests using various combinations of today's, yesterday's, and day-before-yesterday's TSP values, it was decided to analyze the children's pulmonary function tests against the three-day average of today's, yesterday's, and day-before-yesterday's air pollution measurements.

The goal of the acute effects study was to attempt to determine whether children's pulmonary function measurements taken on low-pollution days were significantly better than measurements taken on high-pollution days. In an attempt to answer this question, two major factors had to be taken into account; i.e., (1) the child's size as measured by height, and (2) the differences among children of the same height in terms of pulmonary function ability. The variability produced by the two factors was large, so that no valid conclusions about acute effects of air pollution on pulmonary function could be made without adjusting for these factors in the statistical analysis. These problems were resolved by analyzing each child as his/her own control. Whether a child's pulmonary readings were high or low on a given day was relative to that child's pulmonary readings made on other test days. Thus, essentially all the children's pulmonary readings were adjusted to the same overall mean for a particular height.

Results of this analysis indicated that the best pulmonary function readings were recorded at the 0-100 TSP level, the next best at the 101-150 TSP level, and the worst at the 151-200 TSP level. Pulmonary measurements taken on days when TSP was high were worse than those taken on days when TSP was low for both males and females. (Whether the observed differences are physiologically significant remains for the medical profession to decide.) Unfortunately, because 1978-79 pollution levels in Missoula were relatively low, no meaningful observations at three-day average pollution values above 200 ug/m^3 were obtained. (Further testing during the 1979-80 academic year yielded very similar results, except that one of the testing periods in 1980 had a three-day average TSP value of 440 ug/m^3 .)

The results for three-day average respirable fine particulate demonstrated the same pattern as three-day average TSP for FVC and FEV_1 . The results for FEF did not follow the pattern of the others. Again, enough consistency appeared throughout to warrant further study.

The results for three-day average respirable coarse particulate (these levels usually do not reach the deep lungs) were not quite as strong as those for TSP and respirable fine particulate. For FVC, the pulmonary measurements made at all respirable levels essentially were equal. For FEV_1 and FEF, pulmonary measurements made at the respirable coarse levels of 0-30 and 31-60 were very similar. Measurements made at the 61-90 level of respirable coarse were always the worst, although the results were not significant. With the exception of respirable fine's effect on FEF_{25-75} , all higher levels of TSP and respirable fine air pollution were associated with a reduction in children's pulmonary function measurements. Although the reductions were small, ranging from 0.10 to 2.19 percent, they indicated that increased ambient air particulate levels are associated with acute reductions in pulmonary function test performance among a population of normal fourth- and fifth-grade children.

1979-80

During the 1979-80 school year, pulmonary function testing was continued on 120 fourth- and fifth-graders at Russell and Washington elementary schools in Missoula. Analysis of the 1978-79 data indicated a possible acute effect on children's pulmonary function measurements at increased levels of total suspended particulate (TSP). During 1978-79, however, no usable measurements were made on children when the three-day average TSP reading exceeded 200 ug/m^3 . For this reason, a decision was made to attempt to obtain some measurements in 1979-80 on children immediately following periods of high TSP. Data also were to be gathered on clean control days, but because of early air inversions in the fall, no clean days were obtained. (One test day (27 February 1980) had a three-day average TSP value of 440 ug/m^3 .) Testing also was conducted on Friday, 23 May 1980, after schools had been closed for four days due to the Mount Saint Helens' volcanic eruption. TSP levels as high as $11,054 \text{ ug/m}^3$ were recorded in Missoula after the eruption. Sixty-one males and 59 females were tested during the 1979-80 testing period (57 fourth- and 63 fifth-graders). There were 68 students from Russell School and 52 from Washington School.

During 1979-80, the five test days (11/20/79, 12/19/79, 2/19/80, 3/1/80, and 3/26/80) had three-day average TSP levels ranging from 93.3 ug/m^3 to 153.5 ug/m^3 . Although these are not low TSP values, the days were designated as control days for this analysis. Measurements taken on 27 February 1980, when the three-day average TSP was 440 ug/m^3 , were compared to the control days. Measurements taken on 23 May 1980 after four days of very high TSP due to Mount Saint Helens' volcanic ash were also compared to the five control days. The analysis was similar to that used to analyze 1978-79 Missoula acute effects data.

Results of the analysis of the five control days (average TSP, 119.9 ug/m³) versus 27 February 1980 (TSP, 440 ug/m³) revealed once again that pulmonary function readings are lower on high TSP days. The readings were significantly lower for FVC, FEV, and FEF₂₅₋₇₅ for females and FEV for males. These results were consistent with those for 1978-79.

Pulmonary function tests of the fourth- and fifth-grade children before and after exposure to high levels of volcanic ash (11,054 ug/m³) from Mount Saint Helens failed to demonstrate a substantial decrease in pulmonary function after ash exposure. However, a slight decrease in the boys' pulmonary function test results did occur following the ash exposure. All the children took precautions to minimize ash exposure by remaining indoors most of the time or by wearing a mask for limited outdoor activity. In contrast, the children had constantly decreased pulmonary function test results after three days of high urban air pollution (440 ug/m³, three-day average). This finding indicates that whereas urban air pollution may adversely affect children's pulmonary functions, the volcanic ash did not produce similar demonstrable effects. The lack of measured adverse pulmonary function test effects from the ash is probably due either to the protective precautions taken by the children or to the time delay between the highest recorded ash levels and the actual testing day one week later.

Chronic Obstructive Pulmonary Disease (COPD) Panel Study, 1978-79

The purpose of the COPD study was to determine whether air quality could be related to measurements of the pulmonary ability of individuals with known chronic pulmonary diseases. Eighty-four panelists provided some data during the course of the eighteen-month study, and 17 of them provided the maximum amount

of data by having their pulmonary ability recorded on eighteen different occasions (roughly monthly). Sixty-eight panelists had at least six periods in which their pulmonary parameters were measured, and it was these individuals upon whom the statistical analysis was based. Each individual completed an extensive background questionnaire and took a monthly pulmonary function test. In addition, each panelist completed a daily diary of pulmonary symptoms for both the test day and the previous six days. As a result, two distinct sets of data were analyzed for the COPD panel study; i.e., 1) the pulmonary function test, e.g., Forced Expiratory Volume in one second (FEV₁) and Peak Expiratory Flow Rate (PEFR), and 2) the daily diary of pulmonary symptoms. Dr. Rudy Gideon of the Department of Mathematics at the University of Montana in Missoula conducted the analysis of COPD data.

Pulmonary Function Measurements (FEV₁ and PEFR)

The pulmonary measurements FEV₁ and PEFR appeared to be the most useful for analysis of COPD data. Early in the study, the FVC and FEF₂₅₋₇₅ were not recorded properly because of the inability of many panelists to exhale completely into the Jones Pulmonor in the allotted five seconds. Later, the machine was reset to allow for the complete expulsion of air. However, it was felt that the first five seconds should have allowed for an accurate measurement of FEV₁ and PEFR; therefore, these two pulmonary parameters were analyzed for the COPD study, followed by analysis of symptom data.

In general, air quality is a function of the seasons, as winter experiences poorer air quality than summer because of inversions. For purposes of data analysis, therefore, the months of January, February, March, November, and December 1978 and January, February, and March of 1979 were categorized as winter, while April through October of 1978 and April through June of 1979 were

categorized as summer. The winter's TSP average was 121 ug/m³ (236 days), while the summer's average was 81 ug/m³ (310 days). Analysis of these data showed that lower pulmonary ability for both FEV₁ and PEF_R was achieved among the COPD panelists during the colder months. Lower air quality in the winter than in the summer could explain the significance. Results from a separate analysis of the effects of TSP and respirable fine particulate (<2.5 microns) on pulmonary function among the same panelists also revealed that both FEV₁ and PEF_R measurements decreased as TSP levels rose, although only the statistical regression for FEV₁ was significant. It appeared, however, that the seasonal differences in FEV₁ and PEF_R were larger than the differences due to TSP. Nevertheless, the higher respirable fine levels occurred in the winter, while the lower respirable fine levels occurred in the summer. Therefore, one cannot preclude TSP and respirable fine particulate as having influence on the two pulmonary measurements.

Symptom Analysis

The analysis of symptom data was based on the observed and expected number of pulmonary attacks for each day with complete data. The initial data processing followed the technique used in a paper by Stebbings and Hays (1976). Most of the 540 days studied had between 10 and 20 panelists reporting on the status of various pulmonary symptoms: (1) shortness of breath, (2) cough, (3) wheezing, (4) phlegm, (5) self-treatment through medication for lung problems, and (7) the presence of at least one of the first five symptoms. Symptom (6) was a report as to whether the panelist performed up to his/her usual activity level.

Results of this analysis indicated that significant symptom differences between the cooler months (winter) and the warmer months (summer) could be associated with a number of causes, including differences in the respirable fine

particulate levels found between the two seasons. It was found that cough, wheezing, and usual activity level (symptoms 2, 3, and 6) were clearly worse in the winter than in the summer, and the presence of at least one of five symptoms and shortness of breath (symptoms 7 and 1) were possibly worse, while phlegm and self-treatment through medication for lung problems (symptoms 4 and 5) showed no seasonal differences.

Conclusion

Results of the five-community study showed that children from Great Falls, with the least ambient air pollution, had the highest levels of pulmonary function test performance. Children from Missoula, with the highest ambient particulate levels, and Anaconda, with the highest ambient sulfur dioxide levels, had the lowest pulmonary performance. Children from Billings and Butte were found between the two extremes. Evaluation of differences in socio-economic variables among the communities failed to explain the differences in pulmonary performance among the communities. The study also revealed that in most cases females reacted more adversely to air pollution than males.

The analysis each year of eight months of repeated pulmonary function measurements among Missoula children during 1978-79 and 1979-80 showed that as TSP and respirable particulate levels rose, pulmonary ability decreased. A significant decrease in children's pulmonary function measurements following exposure to extremely high levels of volcanic ash (11,054 $\mu\text{g}/\text{m}^3$ per 24-hour average) was not demonstrated in a separate analysis of pulmonary function data conducted after the volcanic eruption of Mount Saint Helens on 18 May 1980, although this can probably be explained by the fact that most of the children remained indoors during the peak ash exposures, and testing was conducted one week after the highest particulate readings were recorded.

Results of the COPD study demonstrated that as TSP levels rose, both FEV₁ and PEF_R decreased. Likewise, analysis of the COPD panelists' daily diaries with respect to respiratory symptoms showed that as TSP levels increased, coughing, wheezing, and shortness of breath also increased, while usual activity level was reduced.

It appears from the data generated by the Montana Air Pollution Study that air pollution is a likely cause of decreased pulmonary function measurements among elementary school children in the study communities and among individuals in Missoula with chronic obstructive pulmonary disease.

CHAPTER V

MUTAGEN SCREENING ANALYSIS

The second largest health effects component conducted under the Montana Air Pollution Study was a screening program using mutagens, proposed and completed by Doctors Guylyn Warren and Samuel Rogers of the Chemistry Department at Montana State University (MSU) in Bozeman. Mutagens are substances capable of causing permanent changes in the genetic material of cells. Measurement of the mutagenic potential of substances through the use of certain bacterial strains recently has become a standard procedure throughout the world to assess the carcinogenicity of substances; i.e., their potential for causing cancer. Mutagen screening is based upon the premise that carcinogenesis and mutagenesis involve damage to the genetic material of cells; Dr. Bruce Ames of the University of California and other researchers have demonstrated that more than 90 percent of carcinogens are mutagens with the likelihood that all mutagens are carcinogens. The tests predict whether a substance will be carcinogenic on the basis of its mutagenicity to certain strains of bacteria.

The first of two screening methods used was the Ames test, a histidine reversion assay identifying mutagens and determining the types of damage they can cause. The test utilizes bacteria strains that have been modified to require an external source of the amino acid histidine in order to live and to multiply. If the bacteria are exposed to a mutagenic substance, mutations will occur in some of the bacteria, causing them to regain the ability to produce their own histidine, and hence to survive. In testing a substance for mutagenicity, the bacteria are grown in petri dishes in a medium that does not provide enough histidine for them to survive. The test substance then is added

to some dishes, leaving others as controls. If more histidine⁺ colonies of bacteria appear in the test dishes than in the control dishes during the growing period, then the test substance is known to be mutagenic.

A modification of the original reversion technique by inclusion of mammalian liver extracts (S9) also permits the discovery of mutagenic substances that cannot be determined by microbes alone. Some known carcinogenic compounds, such as benzo(a)pyrene (BAP), an organic constituent of cigarette smoke, automobile or diesel truck exhaust, and other combustion products, also are mutagenic but only after activation through the addition of mammalian liver extracts (S9) for detection in microbial systems. Mutagens that can be detected only through mammalian enzyme activation are called indirect-acting, while those that do not require activation are called direct-acting. Mutagenic derivatives of BAP or other products have been found in smokers' urine.

In the area of Anaconda-Deer Lodge and Butte-Silver Bow, it is suspected that important carcinogens may be metals or other inorganic compounds, which the Ames test does not detect as effectively as organic compounds. Therefore, a second technique was used; i.e., the Microtiter microbial repair assay sensitive to almost all of the known inorganic carcinogens. The repair assay uses strains of bacteria defective in their ability to repair genetic damage. Any agent that causes such genetic damage increases lethal effects on these repair-deficient strains, in comparison to the normal or wild type, which can repair genetic damage. Other types of genetic damage besides mutation therefore can be detected, such as chromosome breaks, disjunction, and gross toxicity on all strains. At least ten metals can be considered carcinogenic in humans; i.e., arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, nickel, titanium, and zinc. Among these metals, all but iron can be detected in some form in microbial repair assays.

Study Design

Since lung cancer is a respiratory disease for which high death rates have been documented in several Montana counties, especially in Deer Lodge and Silver Bow (see mortality statistics in Chapter VI), the mutagenesis study was considered to be the best available approach to indicate the extent of any mutagenic-carcinogenic materials in the environment of those counties. MAPS used these tests 1) to analyze ambient air filter samples for the presence of mutagenic substances, and 2) to study human populations through analysis of urine samples for the same substances or their metabolites.

The testing of air pollutants is similar to the testing of drugs or chemicals, except that the pollutants first must be filtered from the air and then extracted from the filter medium in the laboratory. Extracting potentially carcinogenic materials from the filter paper without destroying or altering them proved to be difficult. Drs. Warren and Rogers of the MSU Chemistry Department are among several researchers in the country, who are successfully conducting this activity. Analysis of ambient air filter samples was conducted both during urine sampling described below and in 1980 on monthly air filter samples from ten Montana communities to determine mutagen levels in the air of those communities.

The second way in which MAPS utilized Ames test and repair assays was in screening human populations via urine samples; i.e., the chemicals tested for prospective carcinogenicity were substances excreted in the urine, presumably taken into the body from the air, water, or food. The MSU researchers proposed this approach because other studies had shown that heavy smokers, known to have high lung cancer rates, also had demonstrably high levels of carcinogenic metabolites in their urine.

Urine testing was conducted at three elementary schools in Anaconda and Butte, an area where lung cancer rates are high, and at one school in Bozeman,

an area where lung cancer rates are low. During May 1978, samples were collected for urinalysis from forty-three third-and fourth-grade children at Lincoln School in Anaconda and from forty-seven children at Monroe School in Butte. These grades were selected, as in the pulmonary function testing, because the children were young enough to minimize smoking or occupational exposures and old enough to understand the purpose of the study. Parents of the students were asked to complete questionnaires to determine the types of home heating system employed, home smoking habits, occupation, obvious sources of air pollution exposure, and an impression as to the incidence of cancer in the person's neighborhood during the previous five years. Special air samples also were collected on both the days the urine samples were collected and the preceding days.

A second set of urine samples was taken for comparison from the same elementary school children in October 1978. Because the May results had shown an unusual geographical clustering in Butte, an additional school there (Emerson) was included in the October tests to resolve the geographical issue. Testing in Bozeman, used as a clean-air city for comparison with the Anaconda and Butte samples, took place in November 1979.

All of the urine samples with enough volume (200 ml) to be tested were concentrated by column chromatography, and the concentrates were run through Ames' standard plate incorporation tests on strains TA 1538 and TA 1535, with and without activation by S9 microsomal rat liver extracts. (TA 1538 and TA 1535 are two different bacterial strains that can detect two different classes of mutations.) Urine samples with less than full volume were run only on TA 1538 with activation. Those with sufficient remaining concentrate were tested in the Microtiter microbial repair assay. Air filter samples were extracted and analyzed using the same rapid mutagenesis screening methods, although strain TA 98 was found to be the most sensitive for Ames testing of air filter samples.

Results of Mutagen Levels from Ambient Air Samples

Butte-Anaconda Samples, 1978

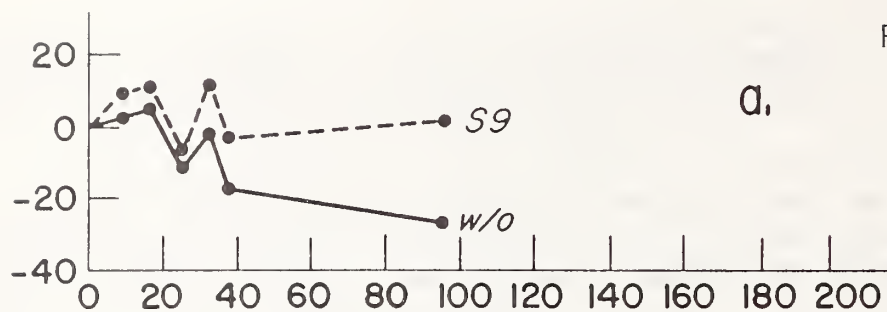
Both the Ames test and the repair assay showed that Butte air samples were more mutagenic than those from Anaconda. Results from analysis of the air filters gathered during the May 1978 sampling period are presented in Figure 5. The two sets of data on each plot indicate results with (indirect-acting mutagens) and without (direct-acting mutagens) S9 activation. Note that the mutagen levels in all six Anaconda filters (Figure 5a) generally are near zero and do not appear to be related to the corresponding levels of total suspended particulate (TSP). Figure 5b for Butte's Hebgen Park site indicates a greater range of mutagenicity over a similar range of TSP levels, with higher TSP levels generally showing greater mutagenicity. Figure 5c shows similar data on filters from the Greeley School site in Butte, which was chosen to provide filters with higher TSP levels.

Determination of Mutagen Levels in Ten Montana Communities, 1979-80

During 1979-80, Drs. Warren and Rogers analyzed air filter samples from ten Montana communities to determine the mutagenic load per micrograms of particulate per month. A total of 118 filters representing the mean monthly particulate level by community was analyzed. Table 13 presents information on city, air filter load, time of sampling, and available meteorological conditions. Twelve filters from each community, except Great Falls and Libby with eleven each, were received. Ames test results calculated per cubic meter of air per community with Salmonella strain TA 98, with and without mammalian enzyme activation, are presented in Figure 6. Table 14 shows the data divided into several classes, while Table 15 ranks the communities by class totals. The effect of S9 enzyme activation on a community basis is also presented in Table 14.

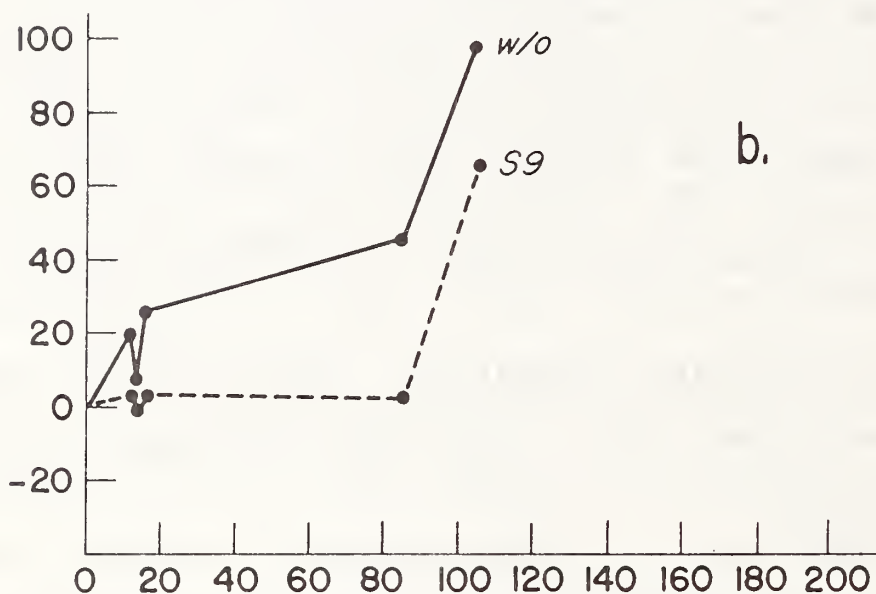
AIR FILTER MUTAGENS: ANACONDA

Figure 5



AIR FILTER MUTAGENS: BUTTE HEBGEN PARK SITE

NUMBER OF HISTIDINE⁺ REVERTANTS PER 0.1ml AIR FILTER EXTRACT
(BACKGROUND SUBTRACTED)



AIR FILTER MUTAGENS: BUTTE GREELEY SITE

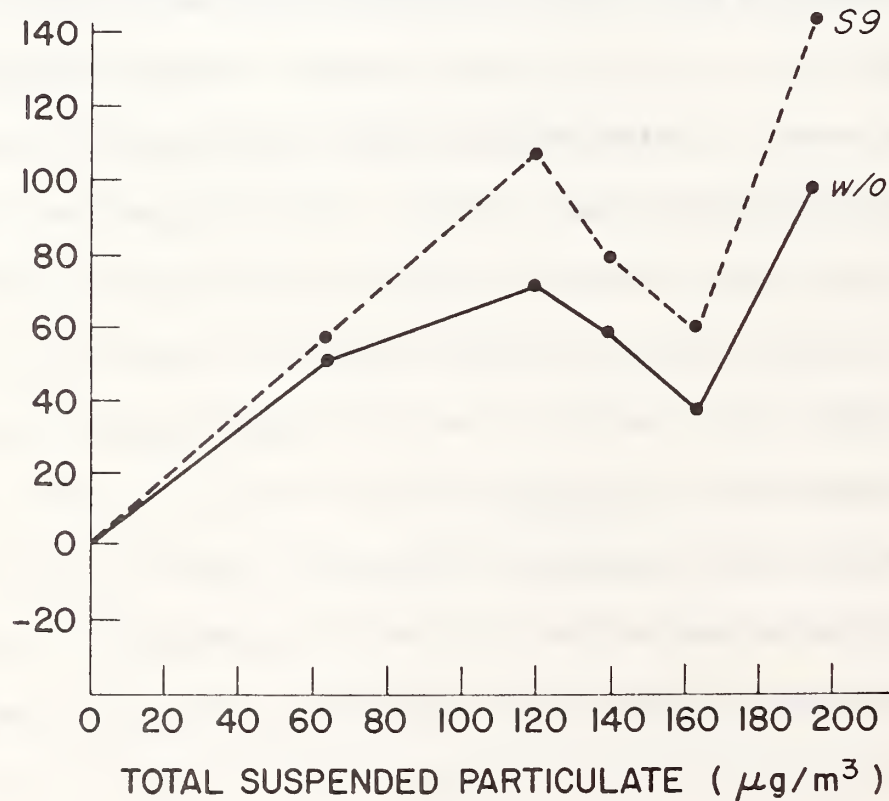


TABLE 13
AIR FILTER INFORMATION

Community	Sampling Period	Particulate (ug/m ³)	Meteorological conditions
			Wind, visibility, sky, humidity, temperature (°F)
1. Anaconda	3/13/79	121	Not available
	4/14/79	36	Not available
	5/15/79	74	Not available
	6/12/79	69	Not available
	7/15/79	48	Not available
	8/16/79	35	Not available
	9/18/79	95	Not available
	10/10/79	161	Not available
	11/16/79	88	Not available
	12/18/79	47	Not available
	1/17/80	46	Not available
	2/17/80	29	Not available
2. Billings	3/16/79	246	Light, clear, clear, moderate, 20-40
	4/12/79	82	Light, hazy, overcast, humid, 20-40
	5/15/79	140	Light, clear, clear, moderate, 61-80
	6/18/79	76	Strong, clear, overcast, rain, 41-60
	7/14/79	84	Not available
	8/16/79	154	Light, hazy, scatter rain, 61-80
	9/15/79	266	Light, clear, clear, moderate, 41-60
	10/17/79	40	Light, hazy, overcast, rain, 41-60
	11/15/79	107	Gusty, clear, clear dry, 41-60
	12/24/79	73	Light, hazy, scatter, moderate, 20-40
	1/19/80	42	Light, hazy, scatter, moderate, 20
	2/14/80	20	Light, hazy, overcast, rain, 20
3. Bozeman	3/16/79	91	Light, clear, scatter, moderate, 20-40
	4/15/79	22	Light, clear, overcast, moderate, 41-60
	5/15/79	61	Light, clear, scatter, moderate, 20-40
	6/14/79	17	Light, clear, scatter, moderate, 41-60
	7/14/79	54	Light, clear, clear, moderate, 60
	8/13/79	20	Gusty, clear, overcast, rain, 41-60
	9/12/79	52	Calm, hazy, clear, moderate, 40
	10/12/79	63	Light, hazy, clear, dry, 41-60
	11/17/79	57	Calm, hazy, scatter, moderate, 20-40
	12/11/79	41	Gusty, clear, scatter, moderate, 20-40
	1/16/80	24	Calm, hazy, scatter, moderate, 20-40
	2/15/80	47	Light, hazy, scatter, moderate, 20
4. Butte	3/19/79	51	Calm, clear, overcast, rain, 30
	4/14/79	98	Light, hazy, overcast, moderate, 35
	5/15/79	155	Light, hazy, scatter, dry, 48
	6/15/79	47	-
	7/14/79	63	-

Community	Sampling Period	Particulate (ug/m ³)	Meteorological Conditions
			Wind, visibility, sky, humidity, temperature (°F)
	8/16/79	24	-
	9/15/79	170	-
	10/19/79	91	Light, clear, scatter, dry, 60
	11/15/79	98	-
	12/18/79	306	-
	1/11/80	22	-
	2/13/80	27	-
5. Decker	3/16/79	41	Light, clear, scatter, moderate, 41-60
	4/15/79	47	Light, clear, scatter, moderate, 41-60
	5/15/79	29	Light, hazy, scatter, moderate, 41-60
	6/14/79	112	Light, hazy, overcast, moderate, 60
	7/14/79	49	Light, clear, scatter, moderate, 61-80
	8/13/79	50	Light, hazy, overcast, rain, 41-60
	9/12/79	21	Light, hazy, overcast, rain, 41-60
	10/18/79	14	Light, hazy, overcast, rain, 41-60
	11/17/79	40	Calm, hazy, overcast, moderate, 40
	12/17/79	70	Calm, hazy, overcast, moderate, 20
	1/16/80	42	Light, hazy, overcast, moderate, 20-40
	2/15/80	27	Light, hazy, overcast, moderate, 20
6. Great Falls	3/13/79	111	-
	4/15/79	38	Gusty, clear, scatter, humid, 41-60
	5/15/79	84	Calm, clear, scatter, moderate, 41-60
	6/15/79	43	Light, clear, clear, dry, 60
	7/15/79	36	Calm, clear, clear, dry, 80
	8/15/79	62	Calm, clear, clear, dry, 80
	9/14/79	60	Light, clear, clear, dry, 60
	10/14/79	55	Light, clear, clear, dry, 61-80
	11/16/79	42	Light, hazy, scatter, dry, 41-60
	12/13/79	50	Strong, hazy, overcast, dry, 20-40
	1/12/80	28	Light, clear, scatter, moderate, 41-60
	--	none	
7. Kalispell	3/16/79	74	Calm, clear, scatter, moderate, 41-60
	4/27/79	117	Light, clear, clear, moderate, 41-60
	5/15/79	118	Calm, clear, clear, dry, 41-60
	6/14/79	51	Gusty, clear, clear, dry, 61-80
	7/14/79	80	Calm, clear, scatter, humid, 41-60
	8/13/79	62	Light, clear, scatter, humid, 61-80
	9/18/79	208	Calm, clear, scatter, dry, 41-60
	10/18/79	30	Calm, clear, overcast, rain, 41-60
	11/17/79	64	-
	12/17/79	58	Calm, clear, overcast, humid, 20
	1/16/80	62	Calm, clear, scatter, dry, 20
	2/15/80	37	Light, clear, clear, dry, 20

Community	Sampling Period	Particulate (ug/m ³)	Wind, visibility, sky, humidity temperature (°F.)
8. Libby	3/13/79	93	Light, hazy, scatter, rain, 20-40
	4/10/79	232	Light, clear, scatter, rain, 41-60
	5/15/79	279	Calm, clear, clear, moderate, 41-60
	6/14/79	228	Light, clear, clear, moderate, 61-80
	7/14/79	105	Calm, clear, scatter, moderate, 61-80
	8/13/79	254	Calm, hazy, scatter, rain, 80
	9/14/79	165	Calm, hazy, scatter, moderate, 60
	10/19/79	56	Calm, hazy, overcast, rain, 20-40
	11/17/79	102	Calm, hazy, overcast, rain, 20-40
	12/17/79	98	Light, hazy, overcast, moderate, 20-40
-	-	none	
	2/16/79	59	Calm, clear, scatter, rain, 20-40
9. Missoula	4/14/79	84	- - - - 47
	5/12/79	79	Light, hazy, scatter, sultry, warm
	6/15/79	60	Light, hazy, scatter, dry, warm
	7/11/79	63	Light, hazy, scatter, humid, cool
	8/12/79	99	Light, hazy, scatter, dry, cool
	9/15/79	115	Light, hazy, clear, dry, cool
	10/13/79	101	Light, hazy, clear, dry, cool
	11/19/79	123	Light, very hazy, scatter, snow, cold
	12/17/79	79	Light, mod hazy, scatter, dry, cold
	1/17/80	188	Light, very hazy, scatter, rain, cold
	2/20/80	111	Light, very hazy, scatter, dry, cold
	3/17/80	74	Light, light haze, clear, dry, cold
10. Scobey	3/16/79	9	Light, clear, overcast, moderate, 20-40
	4/15/79	11	Gusty, clear, overcast, humid, 20-40
	5/15/79	28	Light, clear, clear, dry, 41-60
	6/14/79	52	Light, clear, overcast, moderate, 41-60
	7/14/79	32	Gusty, clear, scatter, dry, 41-60
	8/19/79	53	Light, clear, clear, dry, 61-80
	9/18/79	38	Light, clear, clear, dry, 41-60
	10/18/79	15	Light, clear, scatter, dry, 40
	11/11/79	6	Calm, hazy, overcast, dry <20
	12/17/79	12	Light, clear, overcast, dry, 20
	1/22/80	7	Light, clear, clear, dry, <20
	2/9/80	34	Light, clear, clear, dry, <20

Figure 6

MEAN MONTHLY AIR FILTER MUTAGEN LEVELS FOR TEN MONTANA TOWNS

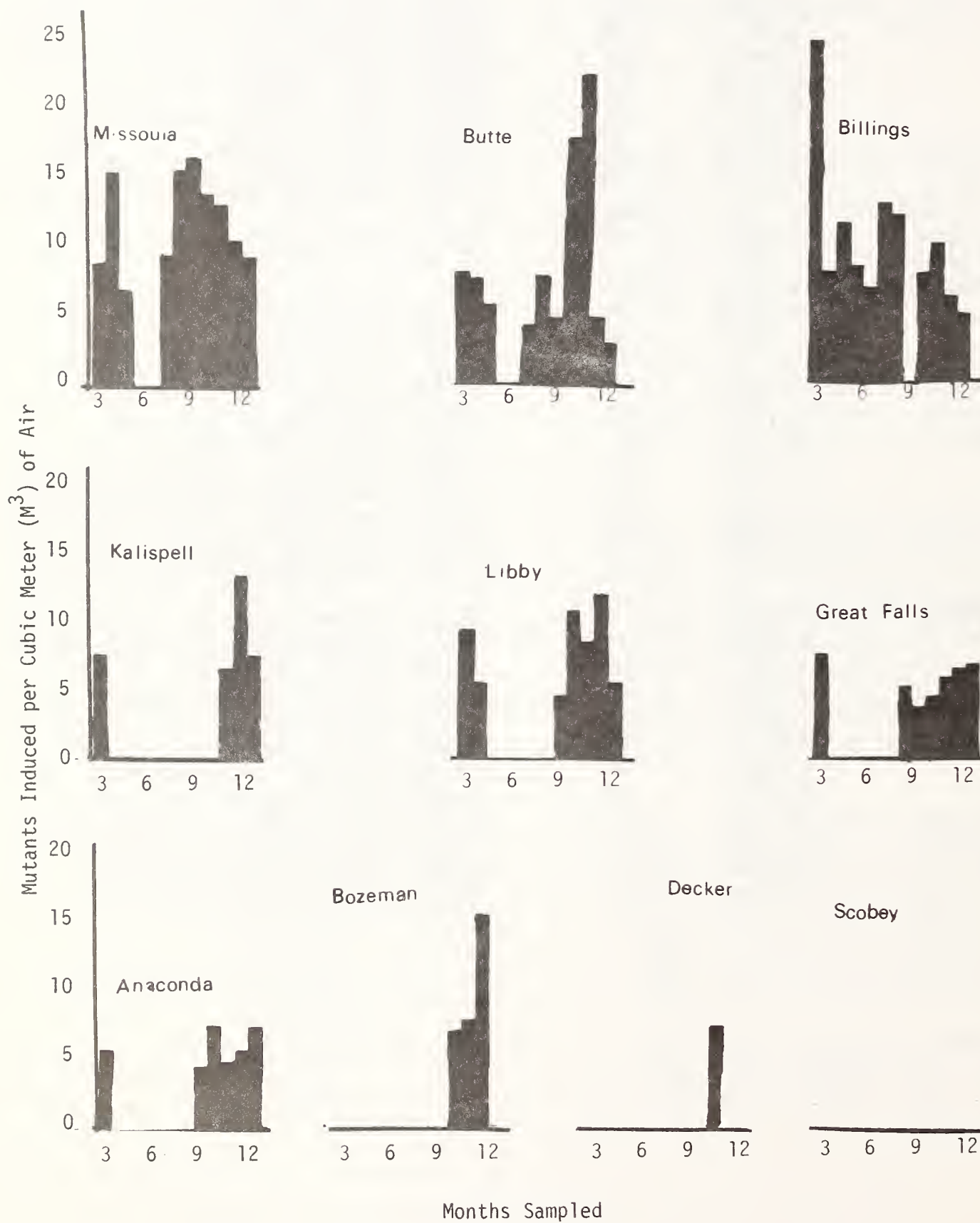


TABLE 14
NUMBER OF MONTHLY SAMPLES
FALLING IN VARIOUS MUTAGEN LEVEL CLASSES
(average number his⁺ revertants per plate above background)

Communities	Class I*		Class II*		Class III*	
	>40		>20 <40		< 20	
	with S9	w/o S9	with S9	w/o S9	with S9	w/o S9
Anaconda	2	1	4	3	6	8
Billings	7	5	2	6	2	1
Bozeman	2	1	1	1	9	10
Butte	5	2	3	6	4	4
Decker	0	0	1	1	11	11
Great Falls+	1	1	4	3	6	7
Kalispell	5	3	2	6	5	3
Libby+	4	0	3	3	4	8
Missoula	8	8	1	2	3	2
Scobey	0	0	0	0	12	12

*Anything 40 or greater is significant at the 95 percent level.

**Twofold above average background is 20, considered mutagenic.

***Definitely negative for mutagen content.

+Only eleven filters available.

TABLE 15

Ranking of Montana Cities/Towns
by

Air Particulate Mutagen Levels (Ames Test)

	Rank	Community	Average Muts/M ³ Air	Pollution* Index
Least Mutagens	1	Scobey	0.00	0.00
	2	Decker	0.60	7.15
	3	Bozeman	2.51	30.09
	4	Kalispell	2.87	34.44
	5	Anaconda	2.98	35.70
	6	**Great Falls	3.54	38.92
	7	**Libby	5.03	55.30
	8	Butte	6.71	80.50
	9	Billings	9.28	111.32
Most Mutagens	10	Missoula	10.08	121.00

*Pollution index = #months positive x average muts/M³ for those months.

**Only eleven months sampled.

Evaluation of the data indicates several obvious trends. For example, the highest mutagen levels in every community occur in the fall and winter, with December the highest month in all cases. On the contrary, the lowest mutagen levels are found in the summer, with July the lowest month. Communities not usually experiencing strong winds to disperse air pollutants from the urban airshed tend to have the highest mutagen levels. Billings may be one exception, but the mutagen levels there are so high that air movement probably is not sufficient to alleviate the problem. Small communities like Scobey on the open plains have the lowest mutagen levels.

In order to investigate further the possible presence of inorganic mutagens in the air filter samples, the MSU researchers analyzed the same extracts from four communities (Anaconda, Butte, Missoula, and Scobey) in the E. coli Microtiter repair assay known to be sensitive to inorganic mutagens. The results show that the Ames test and the repair assay respond to different combinations of toxicants. The data also suggest a possible masking effect of any inorganics by high levels of organic materials. Anaconda and Butte samples scored the most positive repair results, although the results did not exceed a four-fold difference and therefore were not significant at the 95 percent level.

In conclusion, compared to urban mutagen levels calculated by the Environmental Protection Agency (EPA) at Research Triangle Park, North Carolina, winter samples from the cities of Billings, Butte, and Missoula are similar to some samples from urban areas in New Jersey and southern Louisiana. The results of this study of mutagen levels found in air filter samples gathered at ten Montana communities serve as a strong indicator of the presence or the absence of potentially carcinogenic substances in urban airsheds. The information serves not only as a baseline from which to document the impact of particular technological changes in any given area, but also as an indicator of the impact of wood burning in high-mountain valleys.

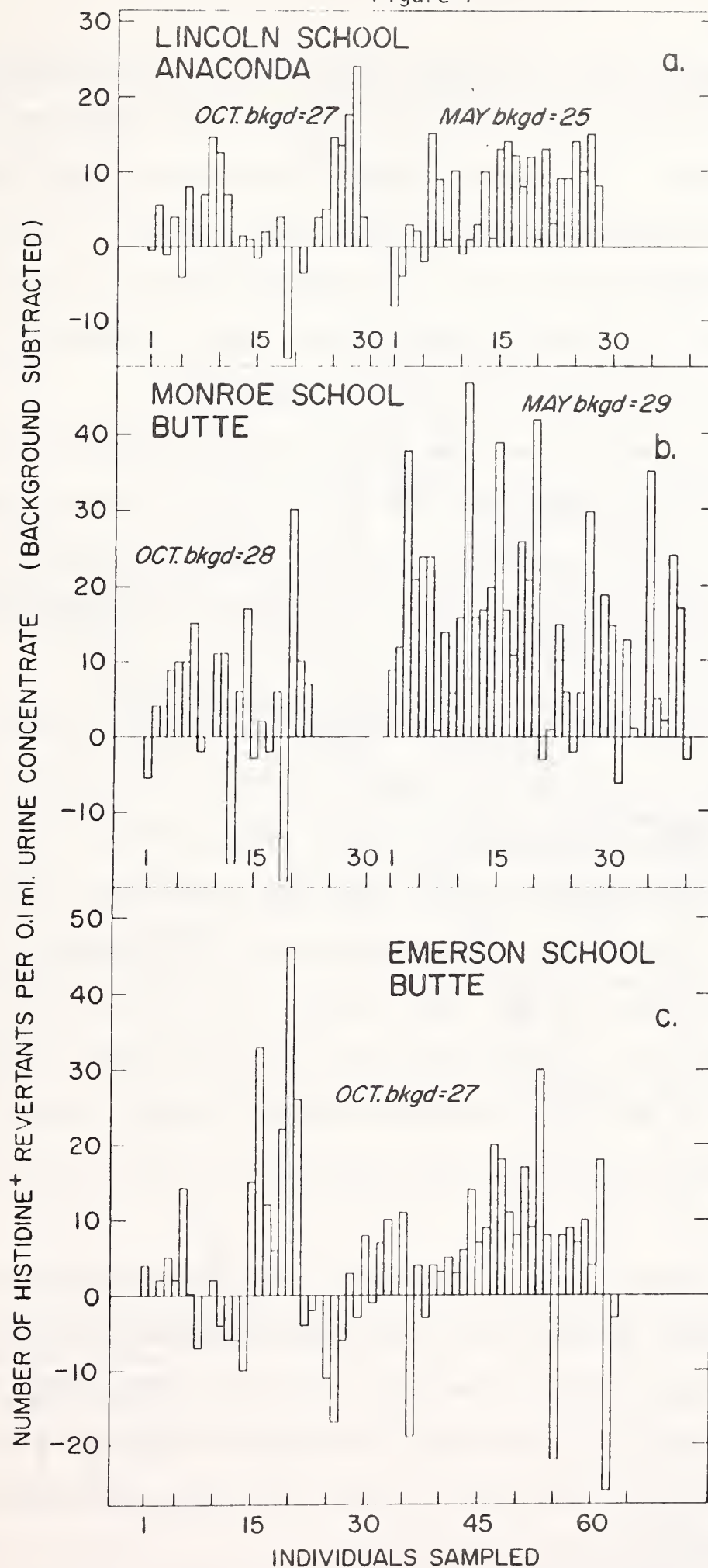
Results from Mutagen Screening of Urine Samples
--from Anaconda, Butte, and Bozeman, 1978-79--
.....

Urine samples were collected at two elementary schools in Butte and at one school in Anaconda in May and October 1978. Figure 7 shows results from Lincoln School in Anaconda, and Monroe and Emerson Schools in Butte, respectively. The Emerson School was sampled only in October. The horizontal dimension of Figures 7a, 7b, and 7c simply indicates the random order in which the individual samples were numbered and has no significance. More variation was found among samples from the Butte schools than among those from Anaconda. Seven students from Monroe School and four from Emerson School had mutagen levels considered to be significantly elevated; i.e., two-fold or more than the normal background levels. No students from Lincoln School in Anaconda reached these levels.

Analysis of urine taken from the Anaconda children during the October sampling, when the Anaconda Company's copper smelter was in full operation, indicated no significant differences from the results of the May samples, taken when the smelter was not in operation. Likewise, results from the October sampling showed mutagen levels at the Butte Monroe School to be higher than those from the Anaconda Lincoln School, although samples from Monroe also had higher mutagen levels than those from the Butte Emerson School. The arithmetic mean of the total number of mutations per sample was 14.6 at Monroe School in May, while it was 6.3 at Lincoln School. The October arithmetic means were 7.7 at Monroe, 4.6 at Lincoln, and 3.7 at Emerson. These differences suggest that population levels of mutagenicity vary significantly among places and times, an indication that some outside factor(s) may be influencing them.

In May 1978, a positive association was noticed between elevated levels of mutagen in the urine and certain areas of residence. Students living relatively near Front Street, a major east-west thoroughfare running parallel to the

Figure 7



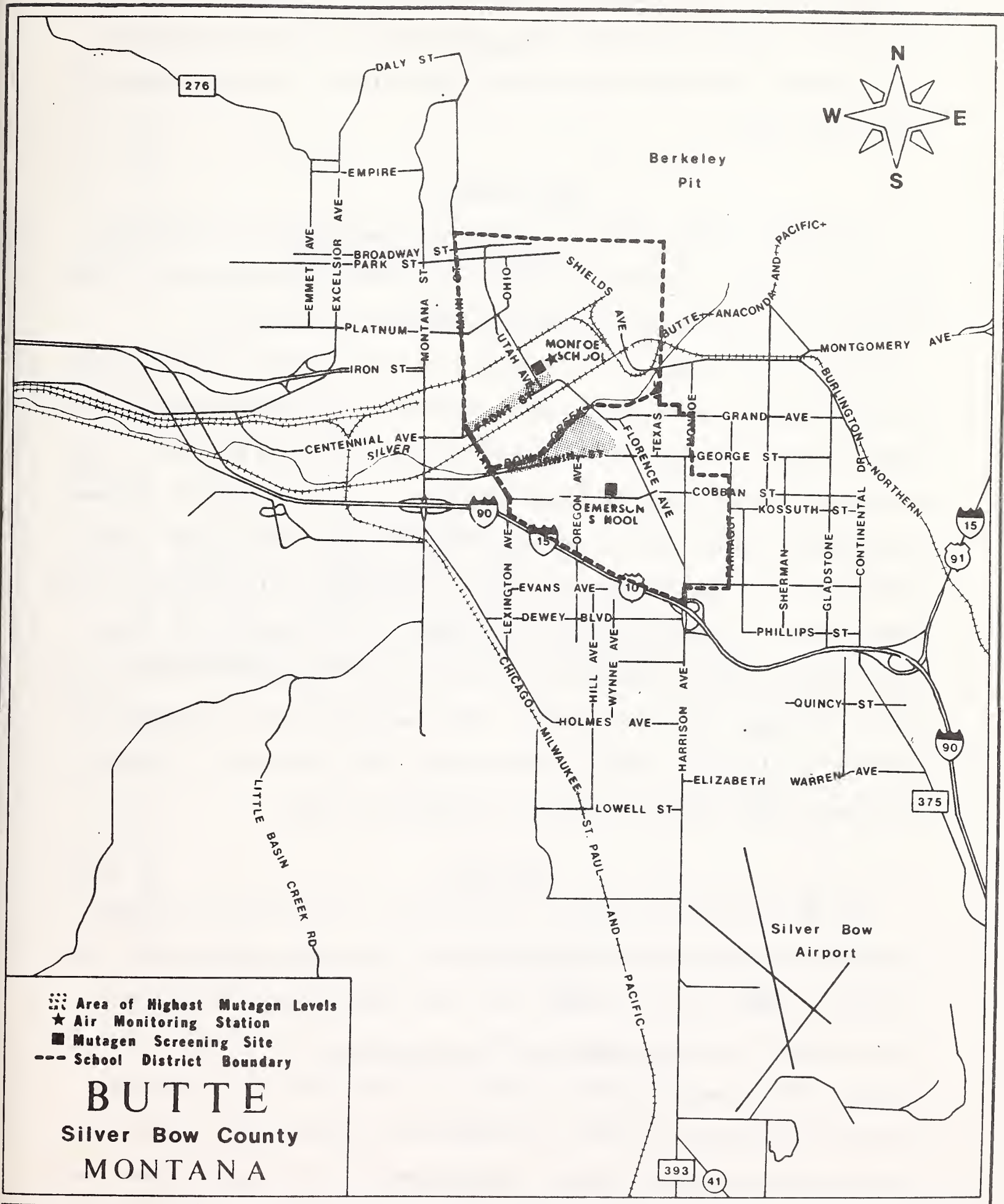
railroad tracks, seemed to have the highest mutagen levels. The results of the October sampling at Emerson school also showed that the four students with the highest levels of mutagen in that school lived relatively near Front Street (see Figure 8). It is not immediately apparent whether this finding is significant, although there is a strong suspicion that the students are being exposed to high levels of diesel exhaust (polyaromatic hydrocarbons, such as benzo(a)pyrene as discussed earlier in this chapter).

Positive Ames test results (two times background) were detected in the students' urine samples using only the bacterial strains that detect a frameshift class of mutation. (Frameshift mutations are caused by the addition of or deletion of one or more base pairs in DNA.) The samples also required activation by S9 microsomal rat liver extracts.

Several urine samples from the October sampling period totally inhibited mutagenesis, even reducing the background mutation levels in the bacteria Salmonella. All such samples were from children living in Butte. The children with the inhibitory samples might have been excreting antimutagens, antibiotics, or possibly a toxic metabolite(s), although no toxicity to Salmonella test bacteria was noted in the Ames testing. Repair assays indicated that one of the inhibitory samples was toxic to repair-deficient E. coli bacteria. According to the questionnaire, that particular student was taking Tofranil, a tranquilizer. It was not clear whether the toxicity to E. coli bacteria could be attributed to Tofranil.

Results of the mutagen screening program in the Butte-Anaconda area have shown that some students from Butte have higher mutagen levels than those from Anaconda. Mutagen load in filters from Butte certainly is higher than in Anaconda. A correlation may exist between high mutagen levels on air filters and in urine in Butte, and the lower levels of both in Anaconda. Further study would be necessary to make this determination.

Figure 8



Ames tests of urine samples from Longfellow School in Bozeman are presented in Figure 9. Mutagen levels were below significance in all but two samples, although higher than those from Anaconda. When tested in the repair assay, all samples were negative.

Metal Analysis

Analysis of October 1978 and November 1979 urine samples from Anaconda, Butte, and Bozeman was performed by atomic absorbance spectroscopy and/or selection assay for trace metals. The results are presented in Table 16.

Butte air particulate is low in arsenic but high in copper and iron. In contrast, Anaconda particulate is high in arsenic. Urine samples from Butte are higher in cadmium and copper, and slightly higher in chromium than are Anaconda's. Anaconda samples average much higher in arsenic content. Bozeman urine samples generally were higher in all tested trace metals, except cobalt, copper, and iron. For Anaconda and Butte, a relationship exists between air and urine levels of arsenic and copper, with arsenic high in Anaconda and copper high in Butte. Three of the Butte urine samples scoring positive in the E. coli repair assay were very high in cadmium, while two of the three also were significantly high in cobalt content. One Anaconda sample, high only in arsenic (0.15 ug/ml), was detected as positive in the repair assay.

Conclusion

The MAPS mutagenesis study has incorporated a new technique for dynamic assessment of cancer risk in human populations. This technique can detect the presence of suspected carcinogens in the immediate environment and determine whether humans are being exposed to those carcinogens. The finding of different mutagen levels between Anaconda and Butte may confirm the existing knowledge that the two communities differ in distribution of carcinoma type and risk pattern for men as compared to women. The documentation of elevated mutagen levels

Figure 9

NO. his REVERTANTS/O.1 ML URINE ON TAI538

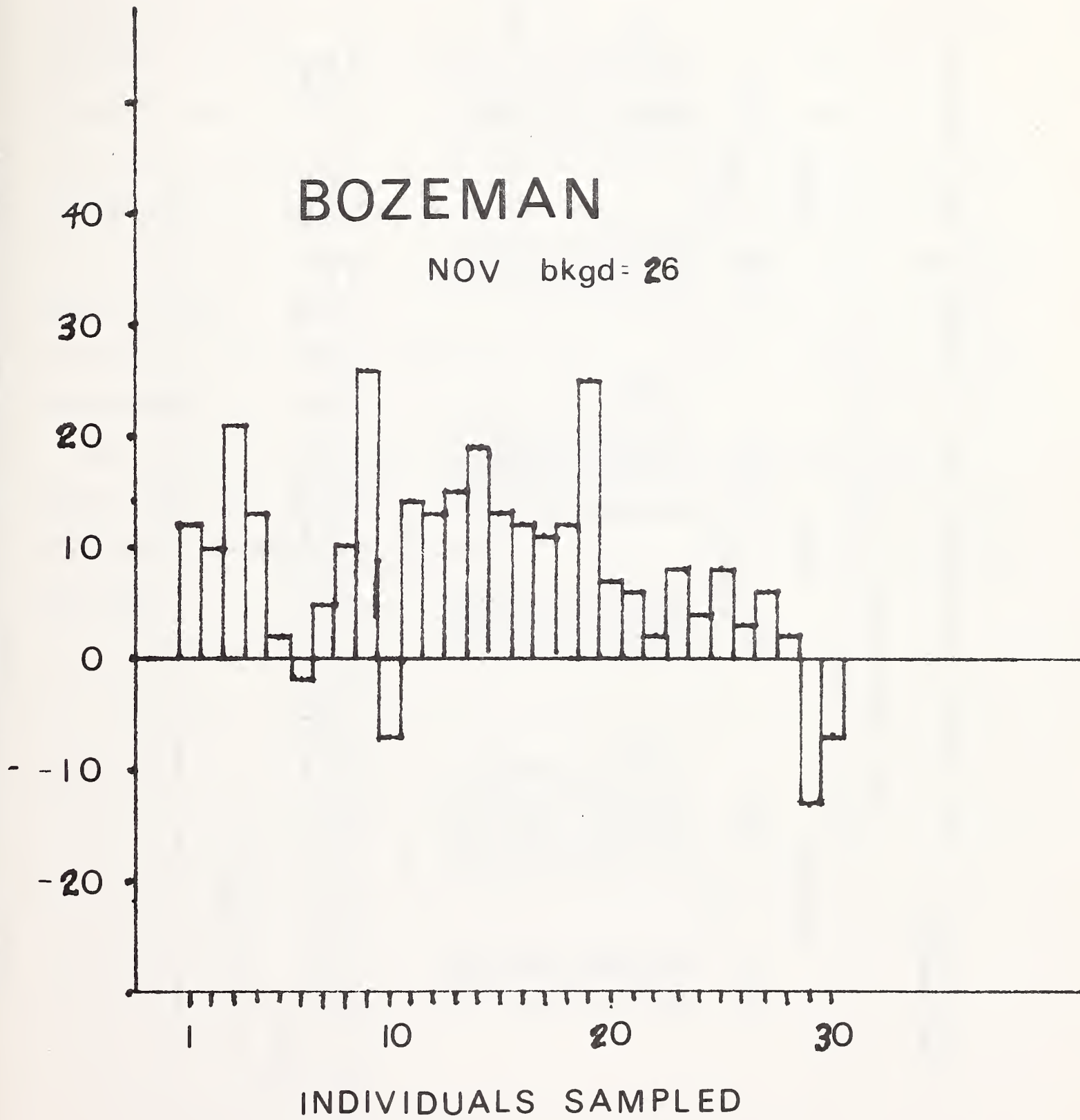


TABLE 16- Metal Analysis of Urine Samples from Anaconda, Butte and Bozeman by Atomic Absorbance Spectroscopy.

Metal	Metal Concentrations ($\mu\text{g/ml}$) by City			BOZEMAN*		
	ANACONDA		BUTTE	Mean (12 samples)	Range	
	Mean (11 samples)	Range (11 samples)	Mean (23 samples)	Range (23 samples)		
As**	0.045	<0.02-0.15	0.013	<0.02-0.05	0.054	0.02-0.11
Be	0.004	<0.003-0.007	0.002	0.003-0.009	0.016	0.006-0.037
Cd	0.001	<0.002-0.002	0.003	<0.002-0.014	0.009	0.006-0.017
Co	0.052	<0.02-0.08	0.044	<0.02-0.16	0.022	<0.02-0.08
Cu	0.037	<0.02-0.05	0.050	<0.02-0.15	0.015	<0.02-0.08
Cr	0.028	<0.01-0.05	0.037	<0.01-0.177	0.042	<0.01-0.06
Fe	0.129	<0.05-0.34	0.106	<0.05-0.33	0.013	<0.15-0.06
Ni	0.035	<0.01-0.090	0.045	<0.02-0.290	0.054	0.022-0.144
Pb	0.012	<0.01-0.04	0.009	<0.01-0.04	0.062	<0.01-0.13
Zn	0.310	0.12-0.71	0.328	0.02-0.70	0.532	0.07-0.93

+ All Bozeman and Anaconda samples were Ames negative, seven of the 23 Butte samples were mutagen positive; three more were positive in the repair assay and all three were high in cadmium and/or cobalt; elevated zinc and beryllium levels correlated with DNA test positives, either Ames or repair.

** By tertiary acid digestion.

* Samples not stored more than 1 week, the rest were stored 3 months before analysis.

in the urine of non-smoking individuals has not been previously accomplished. The application of this technique to human populations has been done only by three other research groups in North America, two in the United States and one in Canada. The geographic isolation of this high risk area (Deer Lodge and Silver Bow Counties) within an area of lower risk than the national averages (Montana, with Bozeman used to represent the state), and the availability of air monitoring, emissions, and epidemiological data make the area valuable for study. As stated by Buffler, 1978, "it is among the subgroups of the population where increases or decreases in risk have occurred for specific primary sites (in this case the lung) that attention should be directed to identify possible environmental carcinogens."

As a result of this study, Dr. Guylyn Warren received a grant from the National Institute of Health to continue urinalysis in Butte. Without the initial funding by MAPS, data attracting such national interest could not have been generated.

CHAPTER VI

STUDIES OF EXISTING HEALTH DATA

A common approach to any epidemiological question is to review and to analyze existing health data pertinent to the given situation. This approach usually is not as sensitive in determining possible relationships as are studies designed specifically for the situation. Nevertheless, because the studies are inexpensive, they should not be omitted. Two specific health data studies, the third and smallest health effects component undertaken by the Montana Air Pollution Study, include a small study of morbidity (illness) through the use of existing data on statewide hospitalizations and an investigation into possible causes of high death rates from lung cancer and respiratory diseases in Deer Lodge, Lake, and Silver Bow Counties. It should be noted that the Air Quality Bureau has not published documents on these two studies; therefore, this report is the only reference available on the results of these studies.

Correlation of Hospitalization Rates with Air Pollution by Montana Counties

Introduction

In searching for an economical, efficient way to monitor the effects of air pollution upon health, an attempt was made to use hospital admissions with respect to respiratory diseases. The Montana Foundation for Medical Care (MTFMC) processes approximately 60 percent of the hospital admissions in Montana. These are hospital admissions paid for by the federal government (Medicare, Medicaid, Indian Service, CHAMPUS, and USPHS). It is recognized that this population represents disproportionate numbers of the low income, the elderly, Indians, and other special socio-economic groups in Montana.

Particularly, it is recognized that this group may have a higher illness rate than the remainder of the population, and moreover, the specific illness rates may be skewed in some manner. However, as the study was relatively inexpensive (less than \$2,000), it was thought worthwhile to ascertain whether this would be a reliable method to monitor the possible impact of air pollution upon health. Dr. Kit Johnson of the Western Montana Clinic in Missoula conducted the study.

Methodology

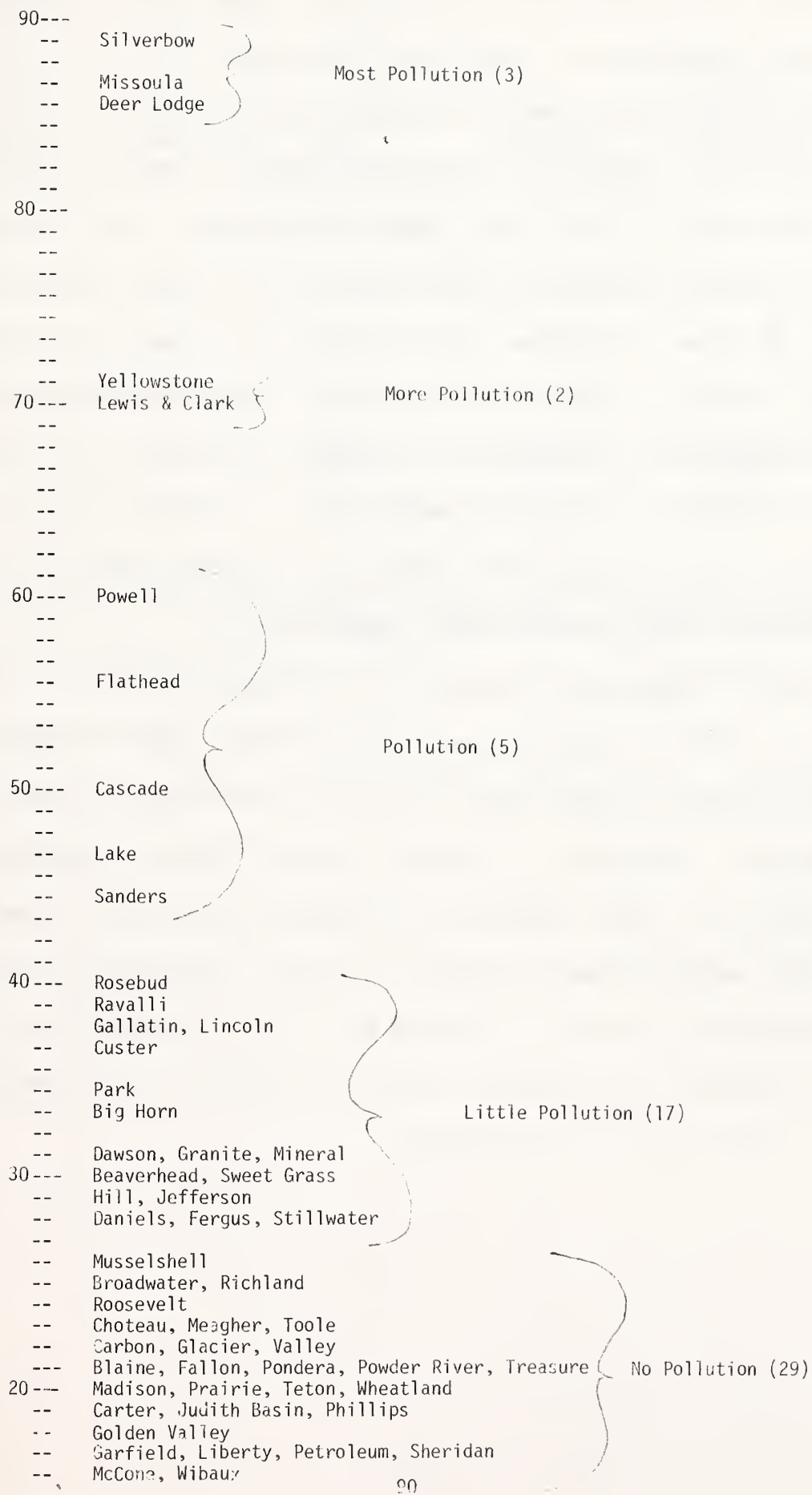
Initially, it was necessary to obtain a reasonable estimate of air pollution levels by counties. Only about twelve counties had any substantial air pollution information available, and this information was not of comparable quality. Therefore, a study to ascertain the counties' relative ranking of air pollution effects upon human health was implemented and conducted during the meeting of the MAPS Advisory Committees (Health, Meteorology, Ambient Air Monitoring, Emission Inventory and Statistical Analysis) on 24-25 July 1978. Twenty-one air pollution experts with an average of six years' work in or study of air pollution in Montana participated in the study. They included nine air pollution specialists, four meteorologists, three physicians, two biologists, one chemical engineer, one statistician, and one respiratory therapist.

Each participant independently assigned a score to each of Montana's fifty-six counties estimating the impact of air pollution upon the health of the citizens of that county, in comparison with other Montana counties. The higher the score, the worse the estimated impact of air pollution upon the population's health. The scores then were summarized and averaged for each county, reproduced in Table 17.

Tables 18 and 19 summarize population, hospital discharges, and disease data for the counties grouped by air pollution levels. It is apparent that a

TABLE 17

MONTANA COUNTIES RANKED BY ESTIMATED IMPACT OF AIR POLLUTION ON HUMAN HEALTH
Air Pollution Scale Relative to Other Montana Counties



negative correlation exists between population density and hospital discharge rates, of which there are three possible explanations. First, a differential age distribution among populations is evident. Urban Montana counties tend to have a younger population than rural counties, which is due to the effect of younger people's migration from rural areas to urban areas, leaving a residually over-balanced, older-age group in the rural counties. The older-age groups have hospitalization rates several times those of the younger- and middle-age groups. The second explanation deals with physician hospitalization practices. If a patient has an illness for which hospitalization is of marginal value, a physician is more inclined to hospitalize a patient living many miles from appropriate medical care than he/she is to hospitalize a patient living within five to ten minutes of appropriate medical care. A third factor is possible high accident rates associated with logging and farming, which are practiced more extensively in the less-populated counties.

Data from MTFMC then were obtained for the two-year period 1 August 1976 through 31 July 1978. These data included the total number of hospital discharges by county and the number of hospital discharges by county for the following specific illnesses: 1) certain mental illnesses (psychoses and neuroses, H.I.C.D.A. codes 3060-3119); 2) certain acute heart illnesses (ischemic and congestive heart disease, H.I.C.D.A. codes 4260 and 4299); 3) certain cerebrovascular accidents (ischemia H.I.C.D.A. 4300-4369); and 4) certain respiratory diseases (acute lower respiratory infections and allergic conditions, H.I.C.D.A. codes 4800-4939).

TABLE 18

POPULATION AND HOSPITAL DISCHARGES FOR COUNTIES
TABULATED BY AIR POLLUTION LEVELS

Summation of Counties by air Pollution Level	Number of Counties	Estimated 1977* Population	Average County Population	Total # of Hospital Discharges 8/1/76 to 7/31/78	Two Year Hospital Discharge Rate/1000
Most Pollution	3	121,300	40,433	17,378	143
More Pollution	2	140,000	70,000	13,189	94
Pollution**	5	156,800	32,267	21,743	139
Little Pollution***	17	180,500	10,529	25,711	142
No Pollution	29	138,500	4,776	25,473	184
	56	737,100	11,216	103,494	140

*Source: "Montana Vital Statistics 1977," The Bureau of Research and Statistics, State Department of Health and Environmental Sciences.

**Powell County data missing

***Lincoln County data missing

TABLE 19

HOSPITAL DISCHARGES AND DISEASES PER COUNTY

COUNTIES	1977* Population	HOSPITAL DISCHARGES				Total
		1-Mental	2-Heart	3-Stroke	4-Respiratory	
MOST POLLUTION						
Silver Bow	40,200	122	200	194	394	7,479
Missoula	66,800	244	198	184	363	6,578
Deer Lodge	14,300	62	98	60	225	3,320
TOTAL	121,300	428	496	438	982	17,378
MORE POLLUTION						
Yellowstone	100,700	176	197	223	335	8,216
Lewis & Clark	39,300	112	244	122	427	4,973
TOTAL	140,000	288	441	345	762	13,189
POLLUTION						
Powell		MISSING DATA				
Flathead	46,400	78	156	144	213	4,587
Cascade	84,400	363	315	237	607	10,895
Lake	17,600	77	60	121	327	4,792
Sanders	8,400	14	41	50	108	1,469
TOTAL	156,800	532	572	552	1,255	21,743
LITTLE POLLUTION						
Rosebud	10,500	18	27	19	138	1,685
Ravalli	19,300	45	59	87	175	2,651
Gallatin	38,500	45	135	98	125	2,364
Lincoln		MISSING DATA				
Custer	13,100	38	33	58	101	2,022
Park	12,500	18	69	43	101	1,571
Big Horn	10,700	35	71	43	334	3,402
Dawson	11,400	30	43	57	115	1,495
Granite	2,700	2	15	7	21	364
Mineral	3,400	9	14	8	27	437
Beaverhead	8,200	10	32	39	71	1,189
Sweet Grass	3,100	8	9	16	31	462
Hill	18,300	88	40	35	487	3,706
Jefferson	7,100	8	24	24	104	1,314
Daniels	3,100	1	12	12	18	341
Fergus	13,300	27	42	43	120	1,908
Stillwater	5,300	14	46	41	40	800
TOTAL	180,500	396	671	630	2,008	25,711

*Source: "Montana Vital Statistics 1977," The Bureau of Records and Statistics, State Department of Health and Environmental Sciences.

Results

Specific disease hospital-discharge rates per 10,000 persons and per 1,000 hospital discharges were analyzed for counties grouped by air pollution levels. Due to the probable distortion of age distribution among the populations, rural counties may have not only higher hospital discharge rates, but also higher hospital discharge rates for special disease categories affecting the elderly, such as respiratory diseases, stroke, and heart disease. This is probably not true with mental illness, which predominates among the young and the urban.

With regard to two-year hospital discharge rates for respiratory diseases per 10,000 persons and per 1,000 hospital discharges, it was found that the most polluted counties not only do not have higher rates of hospital discharges for respiratory diseases, but also the levels there are lower than those from rural, less-polluted counties. It may be postulated that this results from very high respiratory-disease rates among disproportionately large numbers of elderly in the rural counties. It also may reflect a greater willingness among physicians to hospitalize rural and older patients with respiratory illnesses, while urban patients may remain at home.

Conclusion

This study failed to demonstrate a correlation between hospital discharges for respiratory diseases, heart disease, stroke, and mental illness with air pollution's estimated impact on human health in Montana's fifty-six counties. The finding may be attributed to the compounding factors of urban versus rural population distributions, availability of medical care, and other environmental factors.

Investigation of Mortality Rates and Their Possible Causes in Three Montana Counties

Introduction

A 1974 review of Montana's vital statistics by the Department of Health's Bureau of Records and Statistics for the period 1968-1973 revealed that some counties had abnormally high death rates from asthma, chronic bronchitis, emphysema, cerebrovascular disease, and lung cancer, especially in the 40-65 age group. A review of national vital statistics also indicated that mortality rates for chronic obstructive pulmonary disease, which includes asthma, chronic bronchitis, and emphysema, are higher in the relatively dry mountainous states than in the country as a whole (see Table 20). After a thorough analysis of the initial vital statistics information had been completed, three Montana counties (Deer Lodge, Lake, and Silver Bow) were selected for a more detailed investigation of possible causes for the high death rates. (Three significant sources of air pollution are located in Deer Lodge and Silver Bow Counties. The Anaconda Company's copper smelter at Anaconda was the source of approximately 80 percent of all sulfur dioxide emissions in Montana, including emissions from both industrial point and area sources. The Berkeley open pit copper mine in Butte is a source of particulate emissions from haulroad dust, blasting, and fuel combustion in trucks. The third source, the Stauffer Chemical Company's elemental phosphorous plant at Ramsay is a source of fluoride emissions.

(Agriculture and lumbering are the major sources of both employment and air pollution in Lake County, although particulate levels from agricultural tillage and unpaved rural roads are especially high during the dry months of summer and early fall. The lumber industry produces air pollution from a number of sources, including the open burning of logging slash and the disposal of waste wood in tepee burners. The mountain ranges surrounding Lake County prevent the

Table 20-1

Mortality Rates* for Asthma, Emphysema and Bronchitis (ICDA 490-493)
by Geographic Division of the United States

	United States	New England	Mid Atlantic	EN Central	WN Central	South Atlantic	ES Central	WS Central	Mountain	Pacific
1968	16.6	16.9	14.6	16.3	18.7	16.0	14.7	15.5	25.8	17.8
1969	15.4	15.5	13.3	15.9	17.1	14.9	14.8	14.5	21.5	16.4
1970	15.2	15.4	13.6	15.0	16.6	15.1	15.0	14.1	20.5	16.1
1971	14.6	14.0	12.7	14.7	16.3	14.4	13.8	13.8	19.9	16.4
1972	14.8	13.3	12.7	15.5	16.5	14.8	13.9	13.9	19.1	15.7
1973	14.2	13.1	11.9	14.7	15.1	13.8	14.6	13.8	17.7	15.5

*Deaths per 100,000 population

<u>New England</u>	<u>Middle Atlantic</u>	<u>East North Central</u>	<u>West North Central</u>
Maine	New York	Ohio	Minnesota
New Hampshire	New Jersey	Indiana	Iowa
Vermont	Pennsylvania	Illinois	Missouri
Massachusetts		Michigan	North Dakota
Rhode Island		Wisconsin	South Dakota
Connecticut			Nebraska
			Kansas
<u>South Atlantic</u>	<u>East South Central</u>	<u>West South Central</u>	<u>Pacific</u>
Delaware	Kentucky	Arkansas	Washington
Maryland	Tennessee	Louisiana	Oregon
District of Columbia	Alabama	Oklahoma	California
Virginia	Mississippi	Texas	Alaska
West Virginia			Hawaii
North Carolina			
South Carolina			
Georgia			
Florida			
	<u>Mountain</u>		
	Montana		
	Idaho		
	Wyoming		
	Colorado		
	New Mexico		
	Arizona		
	Utah		
	Nevada		

Table 20-2

MORTALITY RATES* FOR ASTHMA, EMPHYSEMA AND BRONCHITIS

(ICDA 490-493)

	United States	Montana	Idaho	Wyoming	Colorado	Oregon	Washington
1968	16.6	26.4	23.9	33.3	25.7	23.0	19.4
1969	15.4	20.2	20.9	23.4	18.5	21.1	17.6
1970	15.2	23.0	24.4	25.3	17.9	20.6	17.1
1971	14.6	20.2	21.0	22.9	20.2	21.6	17.8
1972	14.8	20.1	22.8	25.4	19.9	18.0	17.2
1973	14.2	23.7	18.7	21.5	17.1	18.5	17.2

*Deaths per 100,000 population

dispersion of air pollutants, which is suspected to be a cause of high death rates from respiratory diseases in the county.)

The Air Quality Bureau, under the direction of Dennis Haddow, then applied to the Health Effects Research Laboratory of the Environmental Protection Agency (EPA) for funding and technical assistance to perform a detailed analysis of the elevated death rates. The EPA partially funded and assisted in designing a statewide death-certificate review (Phase I) and a detailed death rate study in Deer Lodge, Lake, and Silver Bow Counties (Phase II). Although EPA partially funded the death rate study in the three counties, the Bureau incorporated it into the overall MAPS project because of its direct relationship to the effort to develop understanding of the effects of air pollution on human health in Montana.

Methodology

In 1974, the Air Quality Bureau initiated a study of death rates in Montana counties for selected respiratory and circulatory diseases. The study was conducted initially through a review of death certificates of persons who had died from the selected diseases during the five-year period 1969-1973.

The diseases selected were as follows:

	Disease Code*
1. Cancer of the respiratory system	~~160-163~~
2. Cancer of trachea, bronchus, and lung	162
3. Cancer of other respiratory system	160, 161, 163
4. Diseases of the circulatory system	390-458
5. Ischemic heart disease	410-414
6. Pulmonary heart disease	426
7. Cerebrovascular disease	430-438
8. Other diseases of the circulatory system	390-458
9. Diseases of the respiratory system	460-519
10. Acute respiratory infections, except influenza	460-466
11. Influenza	470-474
12. Pneumonia	480-486
13. Bronchitis, emphysema, and asthma	490-493
14. Other diseases of the respiratory system	500-519

*According to the "International Classification of Diseases Adapted."

The death rates were calculated for the following categories:

All Ages Total

Male
White
Non-White

Female
White
Non-White

40-64 Years Total

Male
White
Non-White

Female
White
Non-White

0-39 Years Total

Male
White
Non-White

Female
White
Non-White

65 Years and Older

Male
White
Non-White

Female
White
Non-White

The total county populations used to calculate the mortality rates were estimated by the Bureau of Economic Research at the University of Montana in Missoula. The age-specific populations for the period 1969-1973 assumed to comprise the same proportion of the total as in 1970, the census year, taking into account the following formula:

$$\text{County 1970 Age, Sex, Race Proportion} \times \text{County 5-Year Age, Sex, Race Proportion} = \text{U.S. 1970 Age, Sex, Race Proportion} \times \text{U.S. 5-Year Age, Sex, Race Proportion}$$

Death rates were calculated in deaths per 100,000 population for each disease category when at least three deaths were present in an age, sex, and race category. The Chi-square statistical test was applied to the data to determine any statistically significant differences between each Montana county and the national average. Where calculated, death rates for the period 1969-73 among all ages for lung cancer and respiratory diseases are listed in Tables 21 and 22, respectively. The state rates are also listed.

TABLE 21
CANCER OF RESPIRATORY SYSTEM - ALL AGES

<u>County</u>	<u>Rate*</u>	<u>County</u>	<u>Rate*</u>
1. Madison	61.1 +	15. Dawson	30.5
2. Deer Lodge	60.6 ++	16. Lake	29.2
3. Sheridan	58.5 +	17. Cascade	29.1
4. Silver Bow	54.3 ++	18. Big Horn	27.4
5. Musselshell	51.7	19. Hill	26.2
6. Stillwater	49.9	20. Ravalli	26.1
7. Toole	44.6	21. Glacier	25.0
8. Carbon	43.7	22. Beaverhead	24.6
9. Blaine	41.1	23. Yellowstone	23.1 +
10. Flathead	37.8	24. Missoula	22.9
11. Custer	36.9	25. Lincoln	21.2
12. Park	36.0	26. Lewis & Clark	21.2
13. Fergus	34.7	27. Roosevelt	21.0
14. Valley	33.1	28. Gallatin	16.8 +

State Rate 30.1

National Rate 35.5

*Deaths per 100,000 population

+ Significant at 1% level: Chi-Square 6.63 - 10.82

++Significant at 0.1 level: Chi-Square greater or equal 10.83

TABLE 22

DISEASES OF THE RESPIRATORY SYSTEM - ALL AGES

<u>County</u> <u>-----</u>	<u>Rate*</u> <u>-----</u>	<u>County</u> <u>-----</u>	<u>Rate*</u> <u>-----</u>
1. Beaverhead	147.5 ++	22. Valley	72.8
2. Sweet Grass	132.6 +	23. Sheridan	72.2
3. Rosebud	122.1 ++	24. Big Horn	70.4
4. Madison	114.4 +	25. Teton	66.6
5. Lake	112.8 ++	26. Fergus	64.8
6. Sanders	102.5 +	27. Glacier	60.6
7. Stillwater	99.9	28. Fallon	60.5
9. Deer Lodge	93.5 +	29. Chouteau	60.0
10. Meagher	93.3	31. Powell	59.6
11. Carbon	90.2	32. Jefferson	58.9
12. Custer	88.2	33. Hill	58.2
13. Musselshell	87.9	34. Missoula	56.2
14. Ravalli	86.3	35. Yellowstone	50.5++
15. Park	83.9	36. Flathead	50.2 +
16. Roosevelt	83.9	37. Gallatin	49.1 +
17. Blaine	82.3	38. Cascade	46.5 ++
18. Phillips	82.1	39. Lincoln	39.0 +
19. Pondera	80.4	40. Dawson	35.9 +
20. McCone	78.7	41. Richland	34.7 +
21. Toole	75.5		

State Rate 65.4

* Deaths per 100,000 population

+ Significant at 1% level: Chi-Square 6.63-10.82

++Significant at 0.1 level: Chi-Square greater or equal 10.83

Table 23 lists some death rates for Silver Bow County with resultant levels of significance and comparison to overall state rates. It may be noted that Silver Bow County has death rates for almost all disease, age, and sex categories, which are higher than the state death rates. The death rate data for lung cancer are of particular interest, and researchers such as Newman have indicated that Silver Bow County has a high mortality rate for lung cancer. The problem generally has been thought to be associated with males who work in a mining-smelting environment. However, the data in Table 23 indicate that the lung cancer death rates are also high for females in all age categories. The high death rates among females could be caused by exposure to pollutants in the general environment rather than on the job.

Table 24 lists some death rates for Deer Lodge County with resultant levels of significance in comparison to the state rates. The Deer Lodge County death rate data for cerebrovascular disease are of particular interest because the rates are significantly high for both males and females in the 40-64 age group. However, the rates are lower than the state rates for the 65 and over age groups, which could indicate that some causal factor of cerebrovascular disease in the Deer Lodge County environment kills persons at a younger than normal age. (The average age of a female's suffering from a stroke in Montana is eighty-two.)

After review of the initial death rate data, the Bureau approached the Environmental Protection Agency (EPA) for assistance in designing a study to aid in determining the causes for some of the relatively high death rates previously discussed. Two epidemiologists, Dr. Jean French and Dr. Wilson Rigan, from the EPA Health Effects Research Laboratory in Research Triangle Park, North Carolina, helped design a study to aid in determining the contribution of various types of pollutant exposures to the elevated death rates.

TABLE 23

SILVER BOW COUNTY DEATH RATES AS COMPARED TO MONTANA DEATH RATES
Data Taken from 1969-73 Death Certificates

	Silver Bow Co. Rate*	Level of Significance	Comparison to Montana Rate
1. Respiratory Diseases			
a. All Ages	98.8	0.1%	51% higher
b. All Ages - Male	140.3	0.1%	59% higher
c. All Ages - Female	59.4	1.0%	40% higher
d. Ages 40-64	88.2	0.1%	60% higher
e. Ages 40-64 - Male	130.9	0.1%	80% higher
f. Ages 40-64 - Female	47.7		26% higher
g. Ages 65 & Over	573.1	1.0%	25% higher
h. Ages 65 & Over - Male	967.8	0.1%	40% higher
i. Ages 65 & Over - Female	302.3		16% higher
2. Asthma, Emphysema, & Bronchitis			
a. All Ages	331.9	1.0%	42% higher
b. All Ages - Male	567.7	0.1%	59% higher
c. Ages 40-64	42.5	1.0%	70% higher
d. Ages 40-64 - Male	67.1	1.0%	97% higher
e. Ages 65 & Over	159.8		3% higher
f. Ages 65 & Over - Male	364.1		27% higher
3. Pneumonia			
a. All ages	44.0	0.1%	44% higher
b. All Ages - Male	47.1		30% higher
c. All Ages - Female	41.1	0.1%	65% higher
d. Ages 40-64	21.2		15% higher
e. Ages 65 & Over	296.3		32% higher
f. Ages 65 & Over - Male	354.5		24% higher
g. Ages 65 & Over - Female	256.3		48% higher

*Deaths per 100,000 population

4. Cancer of Respiratory System

a. All Ages	54.3	0.1%	80% higher
b. All Ages - Male	83.6	0.1%	69% higher
c. All Ages - Female	26.5	0.1%	148% higher
d. Ages 40-64	93.1	0.1%	63% higher
e. Ages 40-64 - Male	140.9	1.0%	55% higher
f. Ages 40-64 - Female	47.7	1.0%	95% higher
g. Ages 65 & Over	226.1	1.0%	50% higher
h. Ages 65 & Over - Male	421.6	1.0%	53% higher
i. Ages 65 & Over - Female	92.0	1.0%	104% higher

5. Circulatory Diseases

a. All Ages	680.6	0.1%	42% higher
b. All Ages - Male	744.9	0.1%	34% higher
c. All Ages - Female	619.5	0.1%	54% higher
d. Ages 40-64	578.0	0.1%	51% higher
e. Ages 40-64 - Male	802.0	0.1%	44% higher
f. Ages 40-64 - Female	365.7	0.1%	76% higher
g. Ages 65 & Over	4233.9	0.1%	13% higher
h. Ages 65 & Over - Male	5088.2	0.1%	16% higher
i. Ages 65 & Over - Female	3647.5	0.1%	14% higher

6. Cerebrovascular Diseases

a. All Ages	122.7	1.0%	18% higher
b. All Ages - Male	117.3		15% higher
c. All Ages - Female	127.9		21% higher
d. Ages 40-64	65.3		32% higher
e. Ages 40-64 - Male	73.8		36% higher
f. Ages 40-64 - Female	57.2		29% higher
g. Ages 65 & Over	857.7		4% lower
h. Ages 65 & Over	958.2		2% higher
i. Ages 65 & Over	788.6		8% lower

TABLE 24

DEER LODGE COUNTY DEATH RATES AS COMPARED TO MONTANA DEATH RATES
Data Taken from 1969-73 Death Certificates

	Deer Lodge Co. Rate*	Level of Significance	Comparison to Montana Rate
1. Respiratory Diseases			
a. All Ages	93.5	1.0%	43% higher
b. All Ages - Male	129.8	1.0%	47% higher
c. All Ages - Female	56.3		33% higher
d. Ages 40-64	96.0	1.0%	74% higher
e. Ages 40-64 - Male	125.9		74% higher
f. Ages 65 & Over	449.6		9% higher
g. Ages 65 & Over	802.0		16% higher
h. Ages 65 & Over	248.0		4% higher
2. Asthma, Emphysema & Bronchitis			
a. All Ages	37.9	1.0%	69% higher
b. All Ages - Male	54.9		54% higher
c. Ages 40-64	44.0		76% higher
d. Ages 65 & over	197.8		27% higher
e. Ages 65 & Over - Male	343.7		20% higher
3. Pneumonia			
a. All Ages	35.4		16% higher
b. All Ages - Male	47.4		31% higher
c. Ages 65 & over	197.8		12% lower
d. Ages 65 & Over - Male	275.0		4% lower
4. Cancer of Respiratory System			
a. All Ages	60.6	0.1%	101% higher
b. All Ages - Male	107.3	0.1%	117% higher
c. Ages 40-64	96.0	1.0%	68% higher
d. Ages 40-64 - Male	165.3	1.0%	82% higher
e. Ages 65 & Over	249.8		65% higher
f. Ages 65 & Over	504.1	1.0%	83% higher

5. Circulatory Diseases

a. All Ages	571.1	0.1%	19% higher
b. All Ages - Male	681.5	0.1%	22% higher
c. All Ages - Female	457.9		14% higher
d. Ages 40-64	635.7	0.1%	66% higher
e. Ages 40-64 - Male	960.0	0.1%	73% higher
f. Ages 40-64 - Female	300.7		45% higher
g. Ages 65 & over	2976.7	0.1%	20% lower
h. Ages 65 & Over - Male	3368.5	0.1%	23% lower
i. Ages 65 & over - Female	2652.2		17% lower

6. Cerebrovascular Diseases

a. All Ages	131.4		30% higher
b. All Ages - Male	124.8		22% higher
c. All Ages - Female	138.1		30% higher
d. Ages 40-64	119.9	0.1%	143% higher
e. Ages 40-64 - Male	118.0	1.0%	117% higher
f. Ages 40-64 - Female	121.9	0.1%	174% higher
g. Ages 65 & Over	759.8		15% lower
h. Ages 65 & over - Male	779.1		17% lower
i. Ages 65 & over - Female	774.1		10% lower

*Deaths per 100,000 population

The study was divided into the following four areas:

1. A review of death certificates to define a study group consisting of persons who died of cerebrovascular disease, asthma, emphysema, chronic bronchitis, or lung cancer in Deer Lodge, Lake, and Silver Bow Counties during the six-year period 1970-75. Only persons who died before age 70 were considered for this study;
2. Selection of a control group matched by year of death, age, and sex through a review of death certificates of persons who died from causes unrelated to those in the study group;
3. Collection of data from clinical records for both the study and the control groups; and
4. Collection of data about the deceased from the closest surviving relative for both the study and control groups to provide additional information on smoking and occupational/residential history, which is not available from routine death certificates or clinical records.

The Montana Department of Health's Bureau of Records and Statistics reviewed the death certificates of persons who died from the study diseases in the three study counties, and from those certificates identified a study group of approximately 320 persons. Records and Statistics then identified a control group of the same size. The Department thereafter contracted with the Montana Foundation for Medical Care (MTFMC) to collect clinical data on those persons. The staff of MTFMC, composed primarily of registered nurses, contacted hospitals, clinics, and doctors' offices in an attempt to collect the necessary data. However, the MTFMC staff was able to locate clinical records for only about 50 percent of both the study and the control groups. Even the completed forms generally contained limited data.

After initial review, it was decided not to conduct further analysis on clinical data but rather to concentrate efforts on interviewing surviving relatives. The clinical records often were instrumental in identifying surviving relatives. Before the MTFMC staff began to interview surviving relatives, the Department of Health sent a letter to the person to be interviewed. The letter briefly explained the purpose of the study and informed the relative that a representative from MTFMC would be contacting him/her in the near future. The

Department also issued news releases in the study areas to inform the public about the impending interviews.

Several decedents were found in both the study and the control groups for which no relatives nor addresses for such could be identified. Therefore, it was decided to interview as many relatives as could be found for both groups. As it developed, it was possible to conduct only about half of the planned interviews. Some of the relatives were no longer alive, and many had moved, leaving no forwarding address. Many surviving relatives were contacted only after the interviewers had conducted extensive detective work. A general willingness among the surviving relatives to participate in the study was evident, as only six persons in the three counties declined to be interviewed. The number of respondents (successful interviews) and nonrespondents (unsuccessful interviews) broken down by group (study or control), county, sex, and race is shown in Table 25.

Results

Among 226 responses to the question whether the decedents from Deer Lodge, Lake, or Silver Bow Counties were smokers or non-smokers, 181 (80.1 percent) were smokers and 45 (19.9 percent) were nonsmokers. The smoking habits of 17 decedents were unknown. Among these 226 decedents, significantly more male smokers from Silver Bow County were found in the respiratory cancer and chronic lung disease (COPD) groups. Significantly fewer smokers from Silver Bow and Lake Counties were found in the cerebrovascular disease group than in the respiratory cancer and COPD groups when compared to Deer Lodge County.

Significantly more smokers from Silver Bow County were found in the respiratory cancer group than in the control group. Among the total number of males in Silver Bow County (103 persons), 83 were heavy smokers during their lifetimes. Among these, 27 of 29 (93 percent) had respiratory cancer and 14 of 14 (100 percent) had COPD.

TABLE 25

INTERVIEWS OF SURVIVING RELATIVES IN
DEER LODGE, LAKE, AND SILVER BOW COUNTIES

	S T U D Y G R O U P		C O N T R O L G R O U P		TOTAL Resp.	TOTAL Nonresp.	TOTAL Resp.	TOTAL Nonresp.	TOTAL Study & Control
	Resp.	Nonresp.	Resp.	Nonresp.					
Silver Bow	165	89	76	133	61	72	150	148	298
Male	106	61	45	90	43	47	104	92	196
Female	59	28	31	43	18	25	46	56	102
Deer Lodge	1*	23	27	63	26	37	49	64	113
Male	34	15	19	44	18	26	33	45	78
Female	16	8	8	19	8	11	16	19	35
Lake	8	5	3	7	2	5	44	43	87
Male	43	23	20	44	21	23	44	43	87
Female	12	7	5	15	13	16	29	31	60
Total Male	171	92	79	163	74	89	166	168	334
Total Female	87	43	44	77	34	43	77	87	164
GRAND TOTAL	258	135	123	240	108	132	243	255	498

*Subscript indicates each number of non-whites in each group. For example, 50¹ indicates 49 whites and 1 non-white. In this study, all non-whites were Indians.

Among both males and females, significantly more smokers were found in the respiratory cancer group when compared to the control group. Among males, there were significantly more smokers in the COPD group than in the control group. Among both males and females, significantly fewer smokers were found in the cerebrovascular disease group than in the respiratory cancer group.

Conclusion

Because the smoking of cigarettes, cigars, or pipes was such an overwhelming variable in the analysis of mortality data from Deer Lodge, Lake, and Silver Bow Counties, it could not be isolated from the analysis in order to assess other variables. Although it remains strongly suspected that exposure among residents of the three counties to high levels of ambient air pollution has contributed to high death rates there from lung cancer, chronic respiratory diseases, and cerebrovascular disease, it cannot be proven conclusively because the strong presence of smoking overwhelms all other variables. A synergistic effect of air pollution exposure and heavy smoking may be likely. This hypothesis is supported by 1) the findings of decreased pulmonary function measurements among school children in Anaconda and Butte with increased ambient air pollution levels, and 2) the presence of high levels of carcinogenic substances in ambient air filter samples from both communities. Although extensive study was not conducted in Lake County as part of the overall Montana Air Pollution Study, high levels of carcinogenic substances in air filter samples from nearby Kalispell and Libby could indicate similar levels in Lake County. Nevertheless, this study of mortality statistics from three Montana counties confirms the very high correlation between smoking and the incidence of lung cancer or chronic respiratory diseases.

MONTANA AIR POLLUTION STUDY

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